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DOCTORAL THESIS

Open-Ended Intelligence

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Abstract

Faculty of Arts and Philosophy
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Doctor of Philosophy in Interdisciplinary Studies

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How does thought begin? Where does the thinking subject come from? What is cognition and how do objects of cognition arise? This work addresses these problems first by developing a metaphysical foundation and then applying it to develop an open-ended evolutionary systemic framework. The limitations of representation-based, object-oriented thinking are exposed and a way is sought to overcome them and access thought beyond representation. Based on the works of Bergson, Simondon and Deleuze an alternative metaphysics is proposed, one that replaces the individual as the primary *metaphysical element* with individuation as a primary *metaphysical process* and consequently makes difference primal to identity. This paradigmatic shift, it is shown, is the key to going beyond representation and understanding thought and cognition as open-ended, creative processes of self-organization. These formative processes are of a universal scope and precede any kind of representable object, agency, or relation. Specifically they precede the subject-object dichotomy. In bringing forth order from non-order, sense from non-sense, knowledge from the unknown, they manifest *open-ended intelligence* – a kind of intelligence which is neither purposeful or predictive but rather experimental and productive. Guided by this metaphysical approach and in conjunction with the theory of enactive cognition, population thinking and cybernetics, a framework of distributed systemic cognition is developed. It offers conceptual tools that can be applied to the study of complex systems and situations as they evolve.

Keywords: *cognition, complexity, difference, enaction, evolution, individuation, intelligence, interaction, metaphysics, metastability, representation, self-organization, sense-making, thought, virtual*

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To Tyger with respect and love.

Chapter 1

Introduction

1.1 Setting the Stage

> The Lord [Buddha] said: [...] the Bodhisattva, the great being, should produce an unsupported thought, i.e. a thought which is nowhere supported, a thought unsupported by sights, sounds, smells, tastes, touchables or mind-objects. [...] Thereupon the impact of Dharma[1] moved the Venerable Subhuti[2] to tears. Having wiped away his tears, he thus spoke to the Lord: It is wonderful, O Lord, it is exceedingly wonderful, O Well-Gone, how well the Tathagata has taught this discourse on Dharma. Through it cognition has been produced in me. Not have I ever before heard such a discourse on Dharma. Most wonderfully blessed will be those who, when this Sutra is being taught, will produce a true perception. And that which is true perception, that is indeed no perception.
> (Excerpt from the Diamond Sutra, translated from Sanskrit by Edward Conze)

These words, taken from one of the most sacred texts of Mahayana Buddhism, are both cryptic and inspiring. At least to the untrained reader they may seem to be rife with paradoxes at almost every phrase. Nevertheless, the Diamond Sutra, also related as "perfect wisdom", is so called because it is a teaching considered to be so profound that like a diamond it cuts through all the veils of illusion and misconception and can lead the student to ultimate clarity – the realization of the Buddha mind.

I have chosen to open my thesis with an excerpt from the Diamond Sutra, because since I first came across this text, more than 20 years ago, it has inspired me to ask profound questions as to the nature of mind, of thought, of perception, and of cognition. Questions that are clearly put forth or implied in those words given above. What is a thought which is nowhere supported, neither by perceptions nor by concepts (mind objects)? Is there anything like unsupported thought at all? Is there an origin to thought which is beyond or prior to already given perceptions and concepts? How does cognitive activity emerge from the non-cognitive? What is perception? How does it come about? Why and in what sense is true perception no perception?

[1] In Hinduism and Buddhism Dharma is a fundamental concept, referring to the order which makes life and the universe possible. More specifically, it refers to the teachings of the Buddha regarding the nature of the mind and the path to Nirvana or liberation.

[2] Subhuti is one of the Buddha's prime disciples and is known for his powers of reasoning. The Diamond Sutra is presented as a dialogue between the Buddha and Subhuti.

Pursuing these questions and quite a few related ones took me on a journey to many places. This thesis is but a humble and partial attempt to tell the story of this journey, always at its first step it seems, to draw some maps and point towards possible horizons. It is both a philosophical and a scientific exploration but first and foremost it is a personal research trying to understand my own mind, to make sense of sense itself – to get a glimpse of the knowledge through which "cognition is produced in me". As my exploration unfolded, I found it quite fascinating how the more one tries to get to the roots of something ultimately subjective, the more one will eventually encounter highly abstract and universally applicable concepts and principles.

In their seminal work Maturana and Varela (1980, 1987) frame cognition[3] and importantly the concept of observer as biological phenomena and draw some profound consequences based on this framing. A number of these consequences will be thoroughly discussed in this thesis but perhaps the most significant connection made possible by their work is the one existing between cognition and other mental processes and evolution. As was already asserted by Dobzhansky (1973), nothing in biology makes sense except in the light of evolution. Following this line of thought, cognition and other mental activities are certainly no exception; they make sense only in the light of evolution.

As will become clear in the course of this thesis, the connection between evolution and cognition goes much deeper. Not only are cognitive capacities of organisms a product of biological evolution, but cognitive and general mental processes realize in fact evolutionary processes of variation, selection and retention. Furthermore, I will show that cognition can be understood as a fundamental concept that extends evolution and can be applied to general systems, both natural and artificial, at diverse domains and scales. For example: the evolution of a biological species in its environment can be understood as cognitive activity where the said evolving species is an individual cognitive agent cognitively operating at a biological evolution time scale. In other words, cognition, and more specifically cognitive development, as a general phenomenon arising in complex systems can be said to extend the concept of natural evolution.

The importance of Maturana and Varela's work is that it grounded cognition in biology and formed an undeniable continuity from the physical to the biological to the mental. My interest goes yet further, to the metaphysical ground of cognition and mental processes and how they reflect on existence, meaning and value. There is an obvious and unavoidable strange loop (Hofstadter, 2013) here: the cognitive thinking agent trying to make sense of these same sense-making processes that bring forth both her as a subject and the objects of her observation while these are being brought forth. As a result, questions such as how existence (of both observer and observed) comes about, whether there is any intrinsic value to existence per se and how one can know anything at all, are not only very difficult to answer but even to formulate

[3] An in-depth treatment of the concept is given in the body of thesis.

clearly. The point of making the effort to ask these questions is not necessarily for the sake of finding an ultimate truth that is supposedly 'out there' waiting for discovery. The point is rather because such questions stimulate and embody a spirit of incessant inquiry and challenge one to make very profound choices – metaphysical commitments of the kind that guide one's life and are fundamental to a coherent worldview. And again, a worldview as a complex mental object makes sense only in the light of evolution – as the work in progress that it is; both fluid and firm at the same time.

From the perspective of evolutionary theory, life is a product of the ongoing blind processes of variation, selection and retention. The gist of the theory is so simple and so powerful that it can be readily applied to a great number of contexts (Campbell, 1997), and even considered as universal (Dennett, 1995). Most of the psychological resistance to the theory of evolution is because it seemingly strips life, and human existence in particular, of some sort of intrinsic value and sacredness that it is believed to possess, because the theory of evolution, so the popular argument goes, exposes life (and by extension existence) as but a product of a bottom-up process, which is fundamentally blind and therefore meaningless. The conventional story of evolution puts forth as ultimate the final goal of survival and the continuation of that which already exists. Fitness for survival is the only indicator and instrument of achieving this goal, the story goes, and the only possible explanation of why something alive keeps on existing in the face of random change and inexorable entropy. Fitness for survival is nothing more than the ability to resist change successfully and, as the cybernetic version (Ashby, 1957) goes, to keep in range certain essential parameters at the expense of change in other less essential ones. All goals are subjugated to the final goal of survival and survival therefore must be the ultimate value. But this conventional story represents a very narrow and grossly oversimplified account of evolution and of life in general. What is at stake here is not so much a matter of scientifically established fact but rather the particular philosophical perspective through which a scientific theory is interpreted and harnessed to affirm or negate certain values. These have little to do with fact and everything to do with one's worldview, whether it is a product of a conscious critical process or unconsciously acquired. In the former case a worldview is often a jumping board to further insight while in the latter, more often than not, it is an obstruction.

Dobzhansky's provocative statement can of course be read in more than one fashion. Here is another reading of the same words: it is not only that the existence of the living is a product of evolution but that life itself makes sense and gains an intrinsic value *because* it is the medium that allows evolution to take place. There is not much sense, if any, in a life which is arrested, static and existing solely for the sake of existence and the continuation of the same. There is, however, sense in a life that is allowing and inviting growth, the ability to flourish, discovery and perhaps most importantly, the overcoming of its own limitations. Evolution does not strip life and existence of meaning; it is, on the contrary, a prime facilitator of meaning and value.

Making survival a fetish would never allow something positive and life affirming to be seen in change. This perspective is deeply rooted in culture, in language, in perception, in the conceptual systems that facilitate thought and reasoning, and of course in social constructs and the psychological makeup of human individuals. In a nutshell it is a fundamental metaphysical position that prefers the world to be described in terms of being rather than becoming, in terms of final products rather than processes and in terms of identity rather than difference, that prevents one from seeing life not only as the autopoeitic self-preserving process that it is but also as the self-overcoming open-ended process that it is. The very notion of thinking about life (or evolution for that matter) as having a definite purpose or goal is already a symptom of a deeply rooted bias in favour of the constant and against change. There are voices that will immediately attack this view, blaming it for insinuating that life has no purpose at all. But a dialectic of such kind is empty of any credence if not entirely absurd. The view I propose here does not indeed accept that life is subjugated to a single purpose or principle but instead affirms life as having not one purpose but infinitely multiple ones, not one goal but multiple goals and, moreover, the vast majority of these purposes and goals cannot be known *a priori* because they are subject to continuous formative processes of becoming. This is why life as such is open-ended.

Only an attempt to understand life in terms of such multiplicity and openness can avoid the dialectical oversimplification of describing things existing solely as either this or that (the famous Aristotelian principle of the excluded middle). Perhaps this is the point to reflect again on the question of what is an unsupported thought. Presumably all thoughts (and not only) must be supported. They are supported by objects and their relations, that is, ready made *a priori* given definite objects, be they objects of perception or conceptual ones. Support here simply means that conceptually and linguistically thoughts are constituted from *a priori* given definite elements and their relations, which are themselves definite objects, but of a different stratum. Though the concept is extremely useful, I always felt that my understanding of whatever is going on in minds, whether these are thought processes, cognitive processes or even emotional processes, cannot be given entirely in terms of so called supported thoughts. What I find missing are those formative aspects or phases of mental processes that take place prior to distinctions and boundaries and bring these forth. For only *after* such distinctions and boundaries are put forth, can a thought be supported by the objects such processes delineate. I found it tricky to try to shed light on the processes that constitute what can be termed unsupported thought, because there is no straightforward way to reflect on these processes without conceptualizing and objectifying them and by that making them supported. As the Buddha's millennia-old strike of insight teaches, the escape path out of the conceptual prison of existence-only-for-the-sake-of-existence is by producing an unsupported thought that goes beyond all products of mind and reaches the productive. Thereby the problem of unsupported thought is encountered, which also touches on the strange loop problem mentioned above: thought when making itself its own object remains, at least in part, intrinsically unsupported, which affirms its incompleteness and open-ended nature. These two inseparable problems constitute together the problem of the freedom of the mind.

These preliminary reflections about the metaphysical nature of mental processes led me to question the more or less established boundaries between mental concepts from a perspective that tries to examine in depth the fundamental formative processes just mentioned. I realized that I needed to extend my investigation to domains which go beyond what are conventionally considered mental processes, thoughts, perceptions or cognitive activities. I started to find interesting connections that I was not aware of before. The very shift from bounded objects to boundary-forming processes became a new playground and my whole perspective gained an extra dimension of freedom. Within this extra dimension, cognition becomes a concept intrinsic to a very wide variety of systems and processes and designates a dynamic *meeting point* between the known and the unknown, between order and non-order, between sense and non-sense and between the formed, and therefore existing, and the unformed and therefore not yet existing. It is a meeting point that encompasses both metaphysical and epistemological notions and for reasons that will be clarified in the course of this thesis I would rather replace the term 'meeting point', which has an obvious geometrical connotation, with the term *event*, again not in its spatiotemporal connotation but rather as a 'happening of significance'. This event of cognition, or better yet the event of making sense – the primal mental event, all encompassing, both forming and dissolving boundaries, multiple[4] and affirming, I find to be the proper stage to present my research. As the disciple of the Buddha exclaims: "Through it cognition has been produced in me". Much of this thesis is invested in developing the concept that qualifies this kind of event, as far as it can be qualified, while keeping it free from final definition. This is the concept of *open-ended intelligence*. It is the primary actor on the stage just set; hence the title of the thesis.

Setting the stage would not be complete, however, without two additional motifs central to the research. The first is complexity thinking and the second, closely related, the concept of self-organization. Complexity thinking is a paradigm of explanation and description of systems alternative to both reductionist (analysing systems by reducing them to their structural and functional elements) and holistic (analysing systems by identifying their unifying organizing principle(s)) paradigms. Complexity thinking emerged as a set of concepts and methods that are necessary to understand complex phenomena (Heylighen, Cilliers, and Gershenson, 2006; Morin, 1992). Very briefly, a complex phenomenon or system involves some or all of the following characteristics:

- large populations of distributed elements or agents possibly with varying numbers (i.e., elements appear and disappear);

[4] Containing a diversity which cannot be reduced to separate elements. See chapters 3-4 ahead.

- the state-space of the overall system grows exponentially with the number of elements;
- diversity and variety of elements in both structure and behaviour;
- diversity of relations and interactions;
- probabilistic interactions, contingency, partial knowledge;
- reflexive interactions among elements, feedback, circularity, recurrence, direct or indirect self-reference, co-dependence;
- openness – no definite boundaries, elements and the overall system evade clear definitions both structurally and behaviourally; there are no definite inputs and/or outputs (e.g., 'the market', wars, ecosystems, political movements, bacteria species that exchange genetic material etc.);
- multiple levels of granularity – multiple whole-parts relations with both bottom-up and top-down interactions (e.g., cells, organisms, societies).

The consequences of these characteristics are at least in part known from everyday life where many things refuse to behave as we expect them to. Due to uncertain probabilistic behaviours and contingent events, complex systems are often unpredictable or even non-deterministic in principle (Prigogine and Stengers, 1984, p. 261). The large number of elements and their interactions render many if not most of the elements inaccessible to direct observation and/or intervention. An exponentially growing number of possible states prevents learning about the overall characteristics of the system by sampling a limited number of behaviours/states (non-ergodicity). Not only are observers unable to gain full knowledge of the system but even the system's statistical behaviour may remain largely inaccessible. Furthermore, different sampling made by different observers (even with arbitrarily close initial conditions) may often yield different and at times irreconcilable (conflicting) perspectives on the same system. If actual observers happen to be part of the system, the situation might become even more difficult to comprehend. Reflexivity and feedback may be the cause of extreme sensitivity to initial conditions and therefore dependence on indefinite historical trajectories (chaos, non-equilibrium) and long range spatial correlations between elements (criticality). These render a complex system irreducible to separate functional and structural components and defeats reductionist analytical methods. Moreover, cause-effect relations and descriptions become partial, unclear and unreliable due to both circularity and the large number of interacting elements. The distribution and diversity of elements render complex systems asynchronous, which makes it even more difficult to impose a coherent time line of events on the system as a whole. The multiplicity of interactions and structures, the multiplicity of perspectives and multiple levels of granularity, with both bottom-up and top-down interactions (upward and downward causation), all contribute to a dynamic that rarely gives itself to explanation in terms of a single or small set of relatively simple principles, rules or measures. Even powerful statistical tools that work on whole populations tend to fall short. In complex phenomena the devil is, and mostly remains, in the details and these are many, wildly diverse and often hidden. This is only to give the reader a glimpse of why neither reductionist nor holistic methods are fit to address complex phenomena and the humbling challenges that complexity thinking must address. From a scientific point of view, complex systems are troublesome because they often defy one of the most essential requirements of scientific credence: repeatability of experiments. It is clear that in order to achieve certain scientific results complex phenomena must be simplified and put in a kind of a straitjacket that deprives them of many if not most of the characteristics that make them complex in the first place.

Both cognition and evolution, even in their conventional understanding, are complex phenomena when checked against the above list. Whereas conventionally cognition takes place within populations of interacting neurons, diverse both in structure and behaviour, evolution takes place within populations of interacting organisms, again diverse both in structure and behaviour. In both, interactions are largely probabilistic and involve contingencies, feedback, recurrence and co-dependence. Though less immediately obvious, both cognition and evolution display exceptional openness and diverse granularity. It is no wonder therefore that many of the consequences mentioned briefly above are apparent in both, and there is little doubt that they are best approached by complexity thinking. As I initially stage cognition as an 'event of significance' involving both the formed and not-yet formed, the known and the unknown, and involving at once both formation and dissolution of order, here is the proper point to note one of the most significant, if not *the* most significant, characteristics of complex phenomena, that is, self-organization. In its deepest sense (and this will be discussed in detail in the first part of the thesis), an 'event of significance' is an event where organization becomes – comes into being – that is, where no thing of its kind was there before and no thing other than itself brought it forth, like a hand holding a pencil, drawing its own contour in the very movement of drawing. But this is only a poetic metaphor that hides at least as much as it discloses. Self-drawing hands do not spontaneously appear in a vacuum or on the empty canvas, though they might appear as if they do, especially if they are intentionally constructed to simplify things. Self-organization too brings forth organization into a complex state of affairs disclosing a surprising simplicity that may seem to 'just appear', yet simultaneously envelopes (and therefore hides) a no less surprising depth of complexity.

What is organization and what is self-organization? Morin (1992) frames the concept of organization within a so called macro-concept, containing three interrelated conceptual elements: system, interaction and organization. System is a concept that encompasses the relation of a whole to its components, while interaction is the concept that accounts for all the activities, relations and dependencies taking place between the components. "[O]rganization ... expresses the constitutive character of these interactions as forming, maintaining, protecting, regulating, governing and regenerating the system-in short the thing that gives the idea of system its conceptual backbone..." In this Morin goes beyond both understanding organization as the generating structure of a system and as an established relation between structure and an overall global function or behaviour of the system as a whole. For Morin, organization is operational and reflects the bottom-up activities that make systems. But there is more to organization that needs further attention. It is apparent that Morin's interest is in establishing a clear idea of what a system is and in this sense organization serves as a conceptual backbone to an idea. By that, however, Morin presupposes, intentionally or not, an observer – a thinking subject who possesses the idea and for whom the concept of organization together with the two other elements mentioned form a paradigm of understanding, a paradigm that stands independently from actual systems and serves as a manner of representing them to a thinking subject. As my primary interest is how thinking subjects arise in the first place, it is not too early to state that my point of departure regarding ideas and the concepts that constitute them is not taking as given either a thinking subject as the source of ideas or a Platonic transcendent plane where Ideas[5] just exist. In this thesis, following Deleuze, I consider Ideas as immanent to actual configurations and systems in a manner that does not involve a presupposed transcendent thinking subject. Organization therefore is always immanent to actual systems and actual interactions. A thinking subject is itself such an actual system with interactions and organization that allow thinking to take place. I go yet further and argue that systems in general, by the mere fact of being organized can be said to *think the Idea(s) immanent in their organization* independently of an observing subject. Put otherwise, this goes as far as claiming a metaphysical claim: that thinking and being are inseparable. Systems in this sense possess thinking as an extra dimension.

This will be discussed in depth later but here is a relatively simple example: compare a cellular microorganism to a table arranged for dinner. From the perspective of a conventional observer both are systems that comply with the macro-concept described above. But there is, it seems, a fundamental difference between the two: while the microorganism is maintaining its organization autonomously and independently of an external observer, the table arrangement seems to make sense *only* in the presence of an agent, who makes sense of it in the light of many other concepts, the principal of which is 'dinner'. Without these, the table is just an arbitrary arrangement of objects in space without any notion of system, interaction or organization. It is essential for the dinner table to exist *for someone* (or something) that relates to, represents, and/or thinks of it as such. While I would claim that the microorganism 'thinks itself into being', the dinner table does not; it lacks the organizational glue that makes it a system unless it is connected with an observer that completes it into a system. Not only this, in the case of the table, clearly the same physical arrangement can have multiple systemic descriptions that depend on the

[5] The word idea is capitalized wherever it signifies a metaphysical element or construct.

observers involved, while the microorganism as a system is *sufficiently determined* without the involvement of observing agents external to it[6]. What happens to the microorganism's existence when an external observer (e.g., a scientist researching the tiny creature) is added to the picture? The system of the microorganism becomes embedded in another system whose organization is vastly richer in detail and much more complex. Concomitantly the humble Idea immanent in the microorganism thinking itself into being, becomes enmeshed within a network of other Ideas bringing forth a vastly richer and more complex being. But even then, it does pretty well on its own. Nothing fundamental in its constitution has changed. From the perspective of the observing agent[7] it might seem that the richness of knowledge about the inner workings of a living microorganism belongs to her alone, with the difference in scale of comprehension seeming to lend undeniable support to this belief. But this is not so! No idea, no organization, no system so elaborate and complex could be possibly conceived or imagined in the mind of any observer if it was not anchored in the existence of the humble microorganism (or an analogous configuration of a similar degree of complexity). The bottom-up relations are as essential as the top-down relations for rich ideas and organizations to be conceived and come into existence. A fundamental and profound connection is exposed here between the simple and the complex which is not dialectical but mutually affirming, and it is this mutuality that sheds new light on the intimate connection between evolution, cognition and thought.

In the light of this example, and accepting the claim of immanence as fundamental, I wish to claim further that no organization makes sense other than as a self-organization – an organization that brings itself into being on account of the individual interactions it organizes or coheres into a whole. In the majority of cases, when as observers we project organization on a certain arrangement of objects or activities which is not in itself self-organized, we merely fail to consider ourselves as the necessary active component of the system's self-organization. We fail to acknowledge that the representations we construct are interactive elements in a self-organizing process. In short, the kind of cognitive-mental machinery that humans evolved into is a powerful catalyst of self-organization. It not only sees systems everywhere but is critically constitutive to them. This line of thought brought me to consider self-organization as a fundamental and all-encompassing creative process and to believe that investigating the metaphysics of self-organization is an essential philosophical ground work necessary to my research.

The fundamental medium of self-organization is a population of interacting elements where the outcome of interactions affects the occurrence of further interactions. In (Heylighen, 2013), Heylighen notes that: "[T]he outcome of interactions

[6]Not only living systems are sufficiently determined in the sense described here. Physical systems such as stars, atoms, molecules, oceanic streams, weather systems etc. maintain their organization autonomously.

[7]In this example the observer is a human being or an equally competent agency but inasmuch as the microorganism as a system is capable of becoming an element of a larger system – to the extent it is open – the same line of thought applies to systems in general.

is not arbitrary, but exhibits a "preference" for certain situations over others. The principle is analogous to natural selection: certain configurations are intrinsically "fitter" than others, and therefore will be preferentially retained and/or multiplied during the system's evolution." Starting from a situation where all possible interactions within the population are equally probable, as the elements interact, the probability distribution of interactions drifts away from uniformity and is continuously reshaped. This is a process of symmetry breaking, which indeed resembles evolutionary selective processes. However, symmetry breaking alone would not amount to self-organization if not for certain biases in the probability distribution, presenting self-reinforcement tendencies i.e., either positive or negative feedback. Positive feedback is a dynamic where interactions while becoming more or less frequent tend to (directly or indirectly) further increase or decrease respectively their probability of occurrence. Whereas negative feedback is a dynamic where interactions while becoming more or less frequent tend to (directly or indirectly) further decrease or increase respectively their probability of occurrence (i.e., negative feedback works against the trend). Feedback is the essential additional element to symmetry breaking, which also allows retention (memory), amplification and extinction (forgetting) of patterns of interactions and by that actually brings forth self-organization. A vast range of complexity can arise from these very fundamental principles of symmetry breaking and feedback, as the occurrence of every interaction may affect and be affected by multiple symmetry breaking and feedback processes. Non-uniform probability patterns of interactions and relations constitute what is normally called order and allow different degrees of predictability based on previous observations. In special cases patterns become stable or repetitive and constitute deterministic systems. Contrary to dogma, however, fully deterministic systems are the exception rather than the norm.

Self-organization, being often a transient irregular process with partly or wholly undefined characteristics, is very hard to research or even think about. Naturally, both observation and reasoning fundamental to any research are based on finding patterns of organized relations and interactions that are *the product* of self-organization and therefore are already stable, repeating or at least statistically distinct in some aspect. Scientific work aims to single out the systematic and necessitates therefore repeatability and predictability. Theories identify patterns and single out invariants in phenomena and are validated (or refuted) by repeating experiments. In the contemporary scientific paradigm, change that cannot be tamed under invariant principles remains mostly out of reach and this is true with very few exceptions for all scientific disciplines. Even the cases of self-organization that are actually investigated are those where the processes are homogeneous (in terms of their elements and interactions), convergent and less susceptible to contingency, and therefore can be systematically captured by relatively simple organizing principles. The problem of *becoming that precedes being* remains largely within a mental blind spot and as far as the current paradigm is concerned it is simply avoided. My research is set to shed light on the problem by extending the conventional object-oriented thinking into what I call open-ended intelligence. I address self-organization in its broadest manifestation, where irregularity, metastability, conflict, contingency and other 'untamed' elements are not subtracted from the picture and are not simplified away. This very irregular plane of happening shared by self-organizing, evolutionary and cognitive processes, is where the problem of becoming arises and where it needs to be addressed. This requires of course the development of new conceptual and methodological tools that will expose the hidden dimension of generative creative processes underlying the world of consolidated objects and relations.

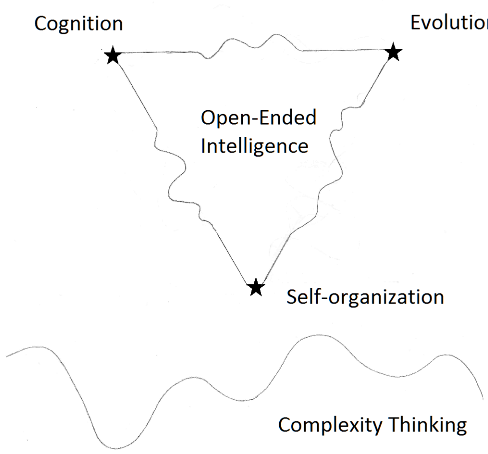

Figure 1.1: A conceptual map of the problem of becoming

Figure 1.1 charts a scaffold for the concept of open-ended intelligence. Complexity thinking is the ground, while evolution, cognition and self-organization are conceptual pillars with foundations deeply embedded in this ground. The curved lines connecting the concepts indicate the complex interrelations between them and simultaneously the fluid boundaries of open-ended intelligence. The dynamism that is missing from the chart is best described as a bootstrapping process that involves all the elements, including the ground.

This should give a palpable idea of the problem I address. I am using the word palpable here because my approach is much more resonant with the intimacy of touch than with the separation and distance characteristic of vision. My goal is not so much to solve a problem but rather to engage in a process of bringing it forth – palpating its boundaries but without ever entirely enclosing it. It is a process that necessarily spans all the way from metaphysical reflection to scientific reasoning and back while leaving both ends open, in touch with each other and hopefully with the reader. I hope to present this research as something that is continuously evolving – an idea in the making but without compromising rigour and nuance.

1.2 On the Method

One of the major considerations that influenced my choices regarding method is the interdisciplinary nature of the study. Interdisciplinary research is a relatively new idea of which many like to refer to its necessity and importance but in which few actually engage. The traditional structure of academic institutions with rigid boundaries between disciplines does not encourage interdisciplinarity. The ideal of an academic career is a lifelong specialization in a narrow set of topics, becoming an expert in a topic almost no one else understands or even knows about. This is an absurdity because the unavoidable consequences of success in this endeavour is isolation from the wider and infinitely richer fabric of knowledge and life at large. From my short experience, it is still hard to publish interdisciplinary research. With very few exceptions, the whole organization of journals and its underlying peer review process is based on the idea of separate disciplines with separate criteria as to the quality and relevance of research. More than once I received warm and encouraging reflections on my work from editors who were nevertheless reluctant to publish it because it was, they felt, too broad or too off topic for their readership. Finally, and perhaps most critically, it is still very hard to receive funding for projects which are explicitly interdisciplinary in nature. The general advice is often not to emphasize the fact that a research project involves an interdisciplinary approach when submitting proposals for funding.

There are of course existing methods for conducting interdisciplinary research, most of them under the broad title of systems theory. One category of such methods draws from the reductionist approach already mentioned above: the interdisciplinary project is systematically divided into modules, each belonging to its appropriate discipline. The modules establish clear protocols of exchanging information and knowledge while generally remaining black boxes in relation to each other. The boundaries between disciplines are crossed on a limited and need-to-know basis. This approach is pragmatically very effective and is driven by necessity. For example, if one sets out to design an artificial valve for heart surgery or a pace maker, diverse disciplines such as physiology, anatomy, material science, mechanical engineering, electronics, chemistry and more are involved and must find a ground of collaboration. But the methodical solutions found in such cases are local and guided by the specific needs of the goals at hand. Another category of complementary methods devised by systems theory draws from an holistic approach, also mentioned above. By abstracting many of the details involved in actual phenomena, it aims to extract and develop principles and concepts that apply to systems in general, no matter what specific discipline is used to represent them. For example, concepts such as state space dynamics, feedback, hierarchy in structure and function, attractors, stability and non-stability, input-output relations etc. do not belong to any specific discipline and apply to all disciplines, given that a phenomenon is represented (following certain formal guidelines) as a system.

Systems theory combining reductionist and holistic approaches indeed offers a powerful methodology. But it is often found to be too abstract and too insensitive to nuance to be effectively applicable as such. For this reason it was consolidated into an independent discipline called systems science with its own definite boundaries and criteria and simultaneously was adopted by various disciplines that modified it to their specific needs at the expense of its overarching generality. In spite of many hopes, systems theory did not become a universal interdisciplinary language and did not manage to significantly dissolve the barriers between disciplines. More recently, however, systems theory made many advances in accommodating complexity thinking into a broader paradigm of systems. Morin (1992) writes:

> The concept of system has always played a fundamental role in defining every set of relations among component parts that form a whole. The concept only becomes revolutionary, however, when, instead of completing the definition of things, bodies, and objects, it replaces the former definition of the thing or the object as something constituted of form and substance that is decomposable into primary elements, as something that can be neatly isolated in a neutral space, and as something subject solely to the external laws of "nature." From that moment on, *the concept of system necessarily breaks with the classical ontology of the object.* (my emphasis)

As I already hinted above, breaking with the classical ontology of the object is a leading direction in my research and also became a guideline in my choice of method. Academic disciplines always present a strong objective identity that has clearly defined boundaries and a uniform coherent field of knowledge within. The monolithic nature of disciplinary knowledge is part of a wider paradigm that pervades the whole academic institution in society. So how is one to conduct an interdisciplinary research and claim knowledge beyond a specific discipline without being apologetic?

The key point for me was to realize that approaching the problem of method itself requires the application of complexity thinking. And this first and foremost implies a break away from the notion that academic disciplines are the monolithic objects they claim themselves to be. Research deserving the title interdisciplinary requires a generalist rather than a specialist approach. In other words, it is set to achieve value through broadness rather than focus of observation and requires therefore its own method. While focus aspires to sharpen boundaries and reinforce them, broadness aspires to exceed boundaries and dissolve them (in the sense of making them fluid, not eliminating them). Broadness has preference for the periphery over the centre of that which is being observed. Broad observation tends to refrain from abstraction, reification, generalization and unification and prefers to highlight the concrete, the unique and the diverse instead. Broad observation seeks to find connections and relations not on the basis of similarity but rather on the basis of difference. It is also much more careful in considering the average and the normalized as the ultimate representatives of a phenomenon and keeps the less probable in sight. But most importantly perhaps, broad observation goes beyond the object, seeking the irregular that allows the regular to emerge, the vague and confused that bring forth the distinct, and the incoherent – not as the negation of the coherent but as the phase that precedes and gives rise to it. In short, broad observation is a perspective that tries to capture not only the product but the productive. Last but not least, it does not come to replace focus but to complement and augment it. From the perspective made available by broad observation the interdisciplinary boundaries are much less clear than presented and disciplinary fields are much less uniform and coherent. Disciplines are naturally inter-penetrating, interacting and organic. Much of what separates them are arbitrary conventions and artificial constructions that though being pragmatic do not represent unassailable truths.

Broad observation as depicted here has become therefore a methodological guideline, a kind of an escape vehicle from dogma. Yet, in the course of my work I found it necessary to develop a more concrete understanding of the term by consolidating and then deploying a number of more specific methodological guidelines. These are listed in the following:

Reflexivity – In second order cybernetics (Heylighen and Joslyn, 2001; Von Foerster, 2007), reflexivity is the property describing the complex relations and influences arising between a system and its observers. More specifically it is an attempt to account for the role of the observer *in the construction of systems*, especially when the observer is explicitly part of the system. In research involving the topics described above and especially the generative nature of cognition and self-organization, reflexivity is unavoidable. Reflexivity touches the interdependence between ontology and epistemology – between what is and what can be known about what is. Once the observer is involved, and I find this involvement necessary to this research, it is not only that what exists is constitutive to knowledge but also that knowledge is constitutive to what exists. In fact I will argue that they co-evolve. In practice, the theoretical framework I develop in the thesis is deployed in the very method of investigation and also in the style of presentation. For example: in the course of research I have produced a few publications, which are included in the third part of the thesis. I did not include them only as the products that they are but also as a reference to an iterative process that reflects how the author as a thinking agent is transforming in the course of writing. In this sense my thesis is constructed not only to report products but also – insofar as it is possible – to expose something of the productive process itself.

Confluence of philosophy and science – The roots of modern science are in what was historically known as natural philosophy, or the study of nature. Science was conceived in the womb of philosophy until it differentiated from philosophy and became an independent paradigm. This process of differentiation took place as the Newtonian worldview, promoting an image of a deterministic mechanistic universe, and the empiricist theory of knowledge consolidated into a more or less coherent and self-sufficient paradigm. It was epitomized by the influential 20th century positivism claiming that all authoritative knowledge can only be achieved by reasoning based on more or less accessible empirical facts.

My point of departure in this research is a problematic of a metaphysical nature but which nevertheless has firm anchors in actual matters. For example, the rise of artificial intelligence and its influence on society. The so-called scientific approach to developing intelligent machines is immensely successful and productive. It is already transforming our lives and in the course of a handful of decades it may become the single most powerful transformative power in all of human history. And yet, as of today, even a not too deep observation discloses the fact that artificial intelligence, though being vastly powerful, is also fundamentally limited as compared to naturally evolved intelligence. Such limitations may have profound consequences as to the future avenues of development open before humanity's technology-based civilization. The problem, it seems, is not technological competence or lack in creativity but rather deeper conceptual barriers in how general intelligence is understood. My investigation targeted at complex creative processes such as cognition, evolution and self-organization aims to find ways to overcome these barriers. It is here that I find the scientific method in its narrow positivist sense too limited. Where the nature of distinction-making is under investigation, and where the complex relations of observer-phenomena are considered, the conceptual ground of the scientific paradigm naturally comes under scrutiny, and particularly the apparent alienation that emerged between science and philosophy. This is why I found it reasonable if not necessary to develop my thinking as a ground of confluence where science and philosophy meet and dynamically redraw their boundaries and relations.

Affirmative reasoning – In my search to apply practically what I termed above broadness of observation, I was strongly influenced by Nietzsche's non-dialectical concept of affirmation and especially Deleuze's reading of Nietzsche in this respect (Deleuze, 2006, chap. 1). What is affirmation and how is it applied as a method? A central element in Nietzsche's philosophy is the concept of force, systems of forces and their interrelations of power, i.e., the asymmetry of dominating - dominated forces. According to Deleuze:

> "the essential relation of one force to another is never conceived of as a negative element in the essence. In its relation with the other the force which makes itself obeyed does not deny the other or that which it is not, it affirms its own difference and enjoys this difference." (ibid.)

Affirmation, in brief, is a manner by which forces or influences relate, interact or even engage in a struggle or conflict without resorting to the negative. The interrelations between ideas can be readily understood in terms of forces because what is significant about ideas is their impact on other ideas, on the formation of concepts, on the development of lines of thought through the consecutive selection of other ideas, and of course on eventual actions. Affirmation therefore is the manner by which relations between ideas can be examined in terms of their differences[8] and how such differences are asserted without exclusion or negation. The practice of dialectics, of opposing ideas to each other in a manner that one becomes a negative element in relation to the other, or that ideas are presented as essentially mutually exclusive is not coherent with affirmative reasoning. On this Deleuze adds:

> "Furthermore, we must ask what does the dialectician himself want? What does this will [i.e., the will to power] which wills the dialectic want? It is an exhausted force which does not have the strength to affirm its difference, a force which no longer acts but rather reacts to the forces which dominate it – only such force brings to the foreground the negative element in its relation to the other. Such a force denies all that it is not and makes this negation its own essence and the principle of its existence." (Deleuze, 2006)

I find that focused observation tends strongly to the dialectic, to the creation of sharp distinctions, to the amplification of opposition and to confirming, at least to a large part, the identity of its object (be it an idea or an empirical fact) through highlighting what it is not. In short, it is using negation as essence. Broad observation, in contrast, tends to be affirmative in nature. It highlights difference but does not necessarily negate. It is inclusive of multiple diverse perspectives. It acknowledges the other, even when there are sharp differences. Most compellingly perhaps is the understanding that selection (as in Darwinian evolution) is ultimately affirmative. There is no negation of that which was not selected and at any instance in the future that which was not selected, even if it became extinct, can in principle return and dominate[9], or become a synergistic element in a greater whole.

When it comes to affirmative reasoning, the dynamic interrelations between ideas are reminiscent of this dynamic of natural selection. Broad observation is more interested in mating ideas and gaining the potential advantage of their difference than in placing them into dialectical confrontations where they compete to negate each other as a means of gaining their own truthfulness. All of

[8]The concept of difference plays a central role in this thesis. In this sense using affirmation as a methodical guideline also emerges from the reflexive relation between method and content.

[9]The elements related in this analogy are individual phenotypic traits and not whole phenotypes, which have complex evolutionary histories that are irreversible.

these make a compelling case as to why affirmation as a methodical guideline supports the direction of broad observation adopted in this research. It is important to note also that affirmation does not mean that anything goes or that all lines can be crossed or redrawn according to whim. The asymmetry of influence and significance between ideas can be made undeniable in many cases. There are ideas which are simply more significant and more powerful than other ideas and establish therefore clear relations of dominance/submission among them. In other cases, concepts and theories might engage in long struggles (even claiming conceptual territories) but even then the goal is dominance not negation.[10]

Significance before truth – Investigating the foundations of cognition and thought, one faces a problem having to do with reasoning itself. Reasoning is supposed to be a major tool of acquiring valid knowledge. But reasoning itself is a tool or a method of thinking and in order to use it one must presuppose it and its competence in achieving its primary objective, that is, to make valid distinctions according to an *a priori* given criterion of truth. Formally, reasoning is a method of establishing the truth or falsity of propositions. But propositions or statements of fact, whether objective or subjective, are already products of some prior mental processes. Moreover, how can the necessary criterion of truth be given or assumed to exist prior to thought itself? In attempting to understand the productive processes that bring forth cognitive and intellectual faculties, including reasoning, as products, one would rather not presuppose either truth, or a method of achieving it. One cannot even presuppose a thinking faculty or a thinking subject. So how one is to proceed with a topic that seems to radically limit the kind of presuppositions that can be made? There is no argument that some method, some systematic approach is necessary. It seems that one must begin from somewhere in the middle i.e., by presupposing a minimal set of necessary presuppositions and then treading carefully backwards.

Affirmative reasoning provides in this case an interesting alternative to conventional reasoning. Because it does not presuppose a criterion of truth or a faculty capable of determining it, it presents a starting point that assumes much less. Instead, affirmative reasoning attempts to map the *significance* of an idea in relation to other ideas from multiple perspectives. Treating ideas as forces, influences or intensities allows them to be related and connected even before their truthfulness or falsity is determinable or relevant. Significance as a guide to reasoning that comes prior to truth and does not have to presuppose it is therefore found to be an important methodical aid in this research.

[10] In the spirit of affirmation, no claim is made that the dialectical is in any way wrong or not useful.

Cross disciplinary knowledge mobility – As a methodological guideline, knowledge mobility means that knowledge elements e.g., methods, models, explanations, organizing principles etc. can be mobilized and applied across disciplinary boundaries. Knowledge mobility can be further categorized into knowledge migration and knowledge integration. The idea behind knowledge migration is that knowledge acquired in one discipline can be adapted and applied to another (and at times very different) discipline. Similarly, knowledge integration means that elements of knowledge that belong to different disciplines can be integrated into a novel body of knowledge with relevance to other unrelated disciplines. Generally speaking, cross-disciplinary knowledge migration is similar to context-independent learning. It is a feature of general intelligence that is still far from being demonstrated by artificial intelligence systems. A major reason for this failure might be that artificial intelligence algorithms are primarily based on principles of abstraction and generalization.

My understanding of knowledge mobility does not exclude these approaches, but is radically different from them by applying what I would term for the moment the *virtualisation of sense*. Neither migration nor integration happen through the application of abstraction and generalization but rather through returning a consolidated knowledge element to, so to speak, a prior embryonic state where its boundaries are more fluid, and its identity is less integrated and cohesive. This may allow it to express differently and connect differently under the constraints of other contexts. The best metaphor to describe this would be the manipulation of highly differentiated somatic cells into becoming pluripotent stem cells and then back into an entirely different kind of highly differentiated somatic cell (e.g., from a skin cell to a neuron). During all the phases of the process the DNA of the cell is the same but there are profound differences in phenotypic expression. Disciplinary knowledge can be treated in much the same way: it has an expression conditioned by a given context that does not exhaust all its potentialities. This relatively crystallized condition can be reversed outside the context to enable other expressions that might become relevant in different contexts. While abstraction and generalization compress and reduce the unique characteristics associated with a certain element, leaving only a skeleton, virtualisation of sense seeks extra degrees of freedom in the element (in the sense it makes). It seeks to make it richer by exposing a *virtual* dimension of undetermined potentialities that are hidden (or suppressed) by a specific actual manifestation. Beyond the metaphor, however, there is a philosophical support to this idea that will be discussed later in the body of the thesis. Practically, the guideline described here prescribes a cultivation of a style of thinking highly supportive to what I called above broadness of observation.

Collaboration – What seems to be necessary to research that spans over multiple disciplines is the development of a diverse and open-ended perspective and style of thinking, and nothing is more effective for this end than the meeting of minds. I find that collaborative research and especially developing a dialogue between researchers coming from different disciplines and trained in different methods is not only intellectually stimulating and fertile but also gives rise almost spontaneously to the kind of broad observation I pursue. In order to create a common ground of understanding that goes beyond a specific discipline, there is a need to create broader explanations and expand conceptual and linguistic boundaries. This becomes much easier when different paradigms are actually presented by different peers. In my experience, the benefits of collaboration are so noticeable that I made it part of my methodical approach and tried whenever possible to organize my work as a collaborative effort.

Importantly, the style of collaboration I have in mind here is inspired both by affirmative reasoning and knowledge mobility. The goal is to attempt and create a broader perspective (or let it self-organize) that integrates paradigmatic differences into a more complex configuration of ideas and relations. Simplification does occur spontaneously but is never artificially imposed at the expense of depth, or the nuances involved. There is no effort or need to hide differences but rather to expose and affirm them (and enjoy it). There is no need to negate or eliminate and there is no need to compromise in order to reach a unified perspective unless it is expressly advantageous because there is no *a priori* assumption that a unified perspective is in any way better than a dynamically interacting multitude. Instead, fluidity and broadness are utilized to bring forth a synergistic diversity that affirms its own significance.

1.3 A short overview of the thesis

The thesis provides a fresh perspective on the nature of cognition and thought in a universal context as depicted in figure 1.1. My effort can perhaps be best described by borrowing artistic terms such as a collage or an installation that presents a new coherence from pieces – ideas that may initially seem unrelated – by connecting them in new ways. In addition to the introduction, the body of the thesis is presented in four parts divided into sixteen chapters.

The first part is a philosophical exploration of how one may break with the classical ontology of the object, what can replace it and to what end. The intellectual 'climate' of this exploration is one influenced by the work of a few noteworthy 20th century philosophers, primarily, Henri Bergson, Gilbert Simondon and Gilles Deleuze (and to a somewhat lesser extent Friedrich Nietzsche). The first chapter explores and criticizes (following Deleuze) the concept of thought, how it is commonly perceived in philosophy – the image of thought, and especially the problem of representation rooted in the ontology of the object. Deleuze's critique opens the door for a radically novel understanding of objects, subjects and mental phenomena in general. The next three chapters present the metaphysical ground underlying the thesis and its evolution from Bergson's duration, through Simondon's individuation to Deleuze's virtual difference. Concepts central to the thesis: difference, repetition, multiplicity, the virtual and actual aspects of reality, Ideas, individuals and the process of individuation, are developed in these chapters.

Chapter 6 synthesizes these concepts into a perspective that highlights the paradigmatic shift which escapes the object: from thinking in terms of the individual as a primary *metaphysical element* to thinking in terms of individuation as a primary *metaphysical process*. In other words, shifting from ontology to ontogenesis. But escaping the object is not the only ambition of this shift. The development of this metaphysical ground is followed by a radical claim: that everything thinks and is thought. Actual existence is depicted as a universal cognitive event – an ongoing creative process of individuation, unpredictable yet intelligent, that is not confined to or captured by any *a priori* principle, structure or dogma (see also chapter 10). This leads to another concept central to the perspective developed here: open-ended intelligence. Open-ended intelligence arises as a result of a triple synthesis between the metaphysical concept of individuation, self-organization in complex systems and a generalized concept of cognition that together constitute what was earlier referred to as the cognitive event in all its dimensions. Open-ended intelligence offers a new style of thinking that highlights and encourages creativity, openness and synergy and contributes a new ground to complexity thinking and the understanding of general intelligence (see also chapter 12).

The second part develops a second synthesis between the philosophy of becoming and the insights of leading thinkers in systems theory, cybernetics and complexity such as Ross Ashby, Ilya Prigogine, Francis Heylighen, Herbert Simon, Humberto Maturana, Francisco Varela and Manuel Delanda, to name a few. Chapter 7 synthesizes the concept of individuation with the theory of enactive cognition developed by Varela and others to yield a concept of systemic cognition and systemic cognitive development (see also chapter 11). Enactive cognition places its emphasis on cognition as a process of sense-making. This approach is further extended and generalized in the chapter. An argument is developed that cognitive activity, i.e., sense-making, can be assigned to every instance of organization to a degree depending on, and in correlation with, the complexity of the interactions that bring it forth.

Chapter 8 focuses on the distributed nature of systemic cognition and highlights the importance of population thinking to understanding the actual processes of individuation and the realization of the metaphysical theory presented in the first part. It explores assemblage theory and introduces a preliminary mathematical formalization of the concept of individuation based on the idea of information integration borrowed from computational neuroscience. Finally the chapter addresses the question of how complex order can plausibly arise from contingent low level interactions in large populations of disparate elements/agents. This issue is further discussed from an additional perspective in chapter 9.

Chapter 9 presents the concept of interaction and its critical role in how stable objects and relations arise from an unbound flow of change (see also chapter 11). The concept of complex adaptive system (CAS) is developed as a general interactive ground and as a field of ongoing individuation. A significant part of the chapter is dedicated to exploring a number of ideas in cybernetic theory that are central to the understanding of interaction and to the overall development of the thesis.

The third part is a collection of five articles written in the course of composing the thesis (four of which were published in journals and presented in conferences). These articles, especially chapters 10-12, are integral part of the development of the thesis. A short description of the topics is given in the prologue to part III.

The fourth, concluding, part includes two chapters: a precis – an extended summary of the thesis, and a conclusion chapter.

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Now that the three basic questions I intended to address in the introduction, the ’why’, the ‘how’ and the ‘what’ are answered in some proximity, I can embark with you, the readers, on the journey I have in mind to share.

Part I

In Search of the Origin of Thought

Chapter 2

The Image of Thought

2.1 What Everyone Knows...

How does thought begin? A beginning must imply a limit or a borderline between thought and something which precedes thought but is other than thought. The first problem one encounters is the necessity to bring into thought something which is other than thought; how else can one think of a beginning? Furthermore, one needs to ask how the limit is crossed, or in other words, what are the conditions for any thought to arise? A second complementary problem would be to ask whether a world prior to thought can even exist? Supposedly it can, but as such it exists only in the thoughts of a thinker who conceives it, which is paradoxical since such a world is necessarily conditioned by thought (and a thinker) and therefore presupposes both. The problem of crossing the limit is therefore double.

One may try to avoid these problems by claiming that thought is the only precondition of itself (i.e., it exists because it exists), and therefore has no limit, neither a beginning nor an end. As promising as this attempt might seem at first, it only exposes a different and deeper kind of presupposition: thought is a naturally given universal capacity – "what everyone knows and no one can deny" – possessed by a thinking subject who just appears to be by merely thinking. As such, therefore, thought requires no further explanation. It appears, however, that one is already trapped within a fine weave of presuppositions that brings forth an image of thought in itself.

In the third chapter of *Difference and Repetition* Deleuze (1994) exposes such an image, which is pre-philosophical and pre-conceptual in the sense that it draws on the naturalness and inherency of thought; a common sense, so to speak, which is universally available and undeniable. Deleuze's project is "a radical critique of this image" and a "rigorous struggle against this image, which it would denounce as non-philosophical".

Descartes' "I think (therefore) I am" is one clear example of employing common sense, as it contains three elements presumed to be universally accessible namely, self, thinking and being, all of which are given to unmediated experience. One would expect that different philosophies would have distinct manners of addressing the beginning (and nature) of thought but it is Deleuze's claim that all philosophies share a common pre-philosophical Image: "According to this image, thought has an affinity with the true; it formally possesses the true and materially wants the true. It is in terms of this image that everybody knows and is presumed to know what it means to think." (Deleuze, 1994, p. 131). It is indeed hardly deniable how simple and appealing to common sense this image is. What is much less obvious, however, is noticing how all thinking, in its supposedly vast variety, is profoundly subordinated to a single dogmatic image. Moreover, Deleuze highlights the deep connection of this image to morality:

> "When Nietzsche questions the most general presuppositions of philosophy, he says that these are essentially moral, since Morality alone is capable of persuading us that thought has a good nature and the thinker a good will, and that only the good can ground the supposed affinity between thought and the True. Who else, in effect, but Morality and this Good which gives thought to the true, and the true to thought?" (ibid., p. 132)

Before going deeper into what constitutes the image of thought, it is worth mentioning that Morality and the Good need not necessarily originate from a transcendent authority (God) or principle. From another perspective the image of thought can be seen in the light of biological evolution. Everybody knows how to live by the mere fact of being alive and everybody knows how to think inasmuch as thinking serves the continuation of life (i.e., survival in the biological sense and the maintenance of identity in the mental/psychological sense). The correspondence of thought to truth derives from the relationships between the living organism and its environment. If the environment is the ultimate condition of the organism's survival, thought must represent it truthfully, that is, in a manner that ensures optimal probability of survival in all interactions. If thought were otherwise oriented it would sooner rather than later bring about the extinction of the thinker. What is morally Good in thought here corresponds therefore to what is selectively good for fitness and is inherent in it. But also from this perspective, thought is not less dogmatic because at its root it is shaped by evolution to resist change and preserve existence (as much as possible) in its present form. Preferring stability over change, it is adaptive rather than innovative, conservative rather than disruptive, purposeful rather than open-ended, even when temporarily it may seem the opposite (e.g., when giving up a certain principle or pattern for a more general one, as the latter is capable of subordinating many more kinds of change while remaining invariant). The image of thought reflects, it seems, a 'reasoning' of survival that precedes any other kind of reasoning in thought and any kind of evolutionary thought. It is expressly biased towards existence (see also 9.3.1).

2.2 The Image of Thought

Space will allow here only a simplified account of the image of thought: "[t]hought is than a representation of the world: a *re-presentation* in our mind of what is already *presented* to us once, already out there." (May, 2005). In his doctoral dissertation Heylighen (1990) adds:

> "Therefore, a representation belongs neither to the realm of matter, of outside objects, of things-in-themselves, nor to the realm of pure mind or Platonic Ideas: it constitutes an interface, it stands in between Mind and Nature, in between subject and object, in between Self and World. You could go even further and say that the concept of representation transcends the classical dichotomy of Mind and Nature: the only things we have got to work with are representations; neither pure ideas nor things-in-themselves exist in any operational sense, they are by definition unreachable ideals. In a certain sense the subject-object dichotomy is an artifact of representation: it is the representation itself which creates a distinction between 'inside self' and 'outside world'."

The mediating function of representation is central to the image of thought. How does it work and what does it imply? Thinking as representation is the concerted work of a number of distinct mental faculties. Deleuze suggests the following model:

> "There is indeed a model, in effect: that of recognition. Recognition may be defined by the harmonious exercise of all the faculties upon a supposed same object: the same object may be seen, touched, remembered, imagined or conceived ... As Descartes says of the piece of wax: 'It is of course the same wax which I see, which I touch, which I picture in my imagination, in short the same wax which I thought it to be from the start.' No doubt each faculty - perception, memory, imagination, understanding ... - has its own particular given and its own style, its peculiar ways of acting upon the given. An object is recognized, however, when one faculty locates it as identical to that of another, or rather when all the faculties together relate their given and relate themselves to a form of identity in the object. Recognition thus relies upon a subjective principle of collaboration of the faculties for 'everybody' - in other words, a common sense [...] it is the common sense become philosophical. For Kant as for Descartes, it is the identity of the Self in the 'I think' which grounds the harmony of all the faculties and their agreement on the form of a supposed Same object." (Deleuze, 1994, p. 133)

Notice that the term common sense relates to two distinct aspects: first it relates to the concerted operation of the faculties within an individual thinker. Second, it relates to thought and what it means to think as common to all thinkers (Williams, 2003, p. 119). Both aspects are instrumental to the image of thought. A complementary aspect to common sense is what Deleuze calls *good sense*. Good sense is the presupposition that each faculty (e.g., perception, memory, imagination etc.) involved in recognition is naturally and inherently fit for its function and performs it spontaneously without effort (e.g., seeing for the eyes, recalling for the memory etc.). The affinity of thought to truth is grounded in this *a priori* fitness that ensures that all the aspects of thought as representation faithfully and consistently correspond to the same aspects in the object being represented. One will always see (seeing is the operation of the faculty of visual perception) a sphere as a round object and will never recall cubes as round. This is what ensures correspondence in recognition. Both good sense and common sense complete each other in the image of thought and constitute together representation. The concerted work of the various faculties ensured by common sense consolidates both the unity of the thinking subject and the object of thought - a double faced, mutually affirming and irreducible unity. It is this very unity that grounds the so called correspondence concept of truth: a proposition is true if and only if it corresponds to the state of affairs about which it is making its claim (May, 2005, p. 75). The profound influence of the image of thought on the history of philosophy and particularly on how philosophy relates to the nature of thought, cannot be overstated:

> "Thought is supposed to be naturally upright because it is not a faculty like the others but the unity of all the other faculties which are only modes of the supposed subject, and which it aligns with the form of the Same in the model of recognition. The model of recognition is necessarily included in the image of thought, and whether one considers Plato's Theaetetus, Descartes's Meditations or Kant's Critique of Pure Reason, this model remains sovereign and defines the orientation of the philosophical analysis of what it means to think." (Deleuze, 1994, p. 134)

There seems to be a compelling if not arresting case in depicting thought as Good – upright and with a profound affinity to truth. If this was not the case, if the operation of the faculties was inherently unstable or unreliable, or if they could not be reliably and invariably coordinated by common sense, in other words, if the presuppositions encoded in the image of thought were not inherently given, what then? How could reliable distinctions be made? How could stable categories and concepts be formed and related? How could identities be established? In short, how could thought possibly proceed at all? There is little wonder that such an image became a dogma in philosophy (and hindrance, as will be argued next).

Although the discourse here does not cover the full extent of the image of thought, the little it does convey already provides a firm basis to the object as the metaphysical element of thought. It is through the mediation of representation that the supposed identity of objects in the world is reflected in the supposed identity of objects of thought, and representation itself is nothing other than a unity of faculties in the unified and self-identical thinking subject they constitute.

A critical question in the context of this thesis remains: how does thought shaped by this image cope with change if its very operation is based on stable elements? At this point[1] a preliminary answer can be given at two levels: the level of principle and the operational level. At the level of principle, there are two options. Either change is being subordinated to a higher conceptual level of organization which is invariant (e.g., the invariant Maxwell equations capturing the dynamics of electromagnetic phenomena, or probabilistic distributions capturing variations in populations or processes), or it is being expelled from thought altogether as irrelevant noise, error or simply inconceivable. In cases where thought fails to progress towards either of these options, it is considered as a local and temporal setback, not a failure of the image in principle. At the operational level, Heylighen (1990, chap. 2) introduces the concept of adaptive representation:

> "The function of the representation is to steer or to guide the interactions between a system and its environment in such a way that the identity of the system is maintained throughout the changes occurring within the environment. This allows the system to adapt, that is to say to change internally in such a way that the external changes are compensated before they can destroy the identity."

Adaptive representation can be operationally understood as mediating a dynamic world to a dynamic subject (given in terms of behaviours) such that certain correspondences (those constituting the subject's identity) remain invariant. As the various objects constituting the world change so do their representations in the subject, but the upright nature of representation itself is kept intact as long as all change is successfully subordinated to invariant elements or rendered irrelevant.

2.3 Critique of the Image of Thought

"What is wrong with the claim that, for anything to be, it must be capable of being recognized [through representation] (Williams, 2003, p. 120)?" Deleuze's critique begins by claiming that the image of thought can constitute only what he calls "an ideal orthodoxy" and by that, "Philosophy is left without means to realize its project of breaking with doxa." (Deleuze, 1994, p. 134). He proceeds by exposing the inherent weakness of recognition as a model of thought, namely, its banality:

> "[...] it is apparent that acts of recognition exist and occupy a large part of our daily life [...] But who can believe that the destiny of thought is at stake in these acts, and that when we recognize, we are thinking? [...] However, the criticism that must be addressed to this image of

[1]The level of principle is further discussed in chapters 5 and 6 and the operational aspect is developed in the second part of the thesis.

> thought is precisely that it has based its supposed principle upon extrapolation from certain facts, particularly insignificant facts such as Recognition, everyday banality in person; as though thought should not seek its models among stranger and more compromising adventures." (Deleuze, 1994, p. 135)

and again later:

> "This text distinguishes two kinds of things: those which do not disturb thought and (as Plato will later say) those which force us to think. The first are objects of recognition: thought and all its faculties may be fully employed therein, thought may busy itself thereby, but such employment and such activity have nothing to do with thinking. Thought is thereby filled with no more than an image of itself, one in which it recognizes itself the more it recognizes things: this is a finger, this is a table, Good morning Theaetetus." (ibid., p. 138)

In the second quote there is already a hint on the kind of thought that Deleuze has in mind. But before getting to that it is worth trying to understand better what is meant by thought being filled with an image of itself. The core critique of representation is its supposition of identity, which has no ground in fact. As was already noted, representation presupposes at least three kinds of stable identity: *a*) the identity of objects of the world (those being represented), *b*) the identity of objects of thought, i.e., the concepts and categories used to represent objects of the world (or self-reflected objects of thought), and *c*) the identity of the thinking subject that coordinates the various operations of representation divided among different faculties (which is complementary to the first identity). There is a fourth, even less obvious, identity encompassing all the other three which must be presupposed, that is, of the representation operation itself. It is expected to be consistently self-identical, to repeatedly operate in the same manner so as to produce stable relations between objects of the world and objects of thought that represent them and to operate and coordinate in that same manner *in all instances of representation for all thinking subjects whatsoever*. Without this last requirement, there is little point in attempting to form a concept of thought in the first place. This is what Deleuze means by thought being filled with an image of itself[2]. Flower objects are identical in as far as the concept flower can be applied to them so that their differences are trivialized or rendered irrelevant. This is identity in concept. Flowers are identical also in as far as one can judge them to share a certain set of qualities so that other qualities are made irrelevant (a plastic flower is still a flower). This is identity by analogy. Flowers are identical in as far as one can oppose them to anything which is not a flower. This is identity by imagination (there is no negation in the world, only in representation

[2]Interestingly, this image aligns with the concept of self-reinforcement in cybernetic systems, as will be shown in chapter 9.

when a concept is determined by drawing its limits). Finally, flowers are identical in as far as one perceives them resembling each other in form (involving all senses). This is identity by perception (for a detailed discussion see: (ibid., pp. 137-138)).

Identities are ultimately stable entities[3]; they cannot be anything but themselves. Aristotle's principle of the excluded middle claims that an object cannot both have and not have a certain property. Consequently, a proposition about an object cannot be both true and false. This principle consolidates identities as stable elements that are given to logical reasoning and consistent linguistic manipulation. The model of recognition as the image of thought is confined only to such self-identical elements and excludes everything else. Change and difference enter this model only when subjugated to a stable principle or rule with a clear identity. A change in location is subjugated to velocity, a change in velocity is subjugated to acceleration and so on until a final invariant is found[4].

It is no secret that the concept of difference is central to Deleuze's metaphysical thought and is critical to how he sees the problem of the beginning of thought. Differences in Deleuze's thought precede any identity and cannot be subjugated to identity[5]. It is such untamed differences that are the harbingers of the *new* and it is the new that is endowed with the power of beginning:

> "The new, with its power of beginning and beginning again, remains forever new, just as the established was always established from the outset, even if a certain amount of empirical time was necessary for this to be recognized. What becomes established with the new is precisely not the new. For the new - in other words, difference - calls forth forces in thought which are not the forces of recognition, today or tomorrow, but the powers of a completely other model, from an unrecognized and unrecognizable terra incognita. What forces does this new bring to bear upon thought, from what central bad nature and ill will does it spring, from what central ungrounding which strips thought of its 'innateness', and treats it every time as something which has not always existed, but begins, forced and under constraint?" (ibid., p. 136)

Deleuze's metaphysical plane is populated by differences that bring forth unstable identities – entities that are alien to the image of thought in that they are always more than themselves, or otherwise different from themselves. Such entities cannot be represented without 'cleansing' them first from their 'aberrations' (May, 2005, pp. 75-76). This 'cleansing' operation is what takes time in recognition. It is important to note here that the distinction between the new (in thought) and the recognizable is not merely temporal. It belongs to an encounter with the unknown, whereas the

[3]Stability and metastability will be further discussed in 5.1 and in 9.3.2, 9.4.1.

[4]There are additional methods of subjugating change such as statistical moments, feedback, replacing variables with relations among variables, compression, dimensionality reduction and more.

[5]An in-depth discussion of the concept of difference and exploration of the uncharted grounds beyond the image is postponed to chapter 4.

recognizable is already wholly within the known. The image of thought is dogmatic precisely because it will not embrace the abnormal, the contingent, the marginal, the unexpected, the deviant etc., which are all the offspring of the new.

Further, the very idea that stable identities faithfully apply to the majority of actual and possible cases, that there are given norms in thought and in the world, must be put under serious scrutiny. It is easy to accept, almost intuitively given, that any representation is always partial and that any object, person, relation or state of affairs contains hidden potentials of change that are never captured by any of its representations. To represent anything as identity, it is necessary to make sharp the distinction between invariant and variant properties, or at least between significant and insignificant variance, so the latter can be left out. Such distinctions are only empirically possible and therefore cannot point at a metaphysical principle that may support the image of thought. Indeed, as Spinoza already said: "we do not know what the body can do" (Deleuze, 1988, pp. 17-18). Bodies as well as minds (and it is argued that even this distinction is superficial and no more than a figure of speech) do surpass any recognition and any representation of them.

Deleuze's critique is a demonstration of a genuine effort to escape the form imposed by the image of thought that necessarily identifies criticism with negation (i.e., arguing that something *is not* what it is recognized to be). His critique does not aim to negate, dismiss or dismantle the image but rather to take it off its centre, disrupt its self-generated stability, extend it and lead it to its limits and beyond these limits[6]. Understanding the full impact of the critique (and its revolutionary implications) would be incomplete, however, without paying brief attention to style – how philosophical constructs are animated to produce an affect that exceeds their conceptual limits. For example, in how the image of thought treats difference:

> "The 'I think' is the most general principle of representation - in other words, the source of these elements and of the unity of all these faculties: I conceive, I judge, I imagine, I remember[7] and I perceive - as though these were the four branches of the Cogito. On precisely these branches, difference is crucified. They form quadripartite fetters under which only that which is identical, similar, analogous or opposed can be considered different: *difference becomes an object of representation always in relation to a conceived identity, a judged analogy, an imagined opposition or a perceived similitude.*" (Deleuze, 1994, p. 138)

Deleuze's use of dramatizing effects such as the allusion to the crucifixion is not merely decorative but outright methodical: style is inseparable from content

[6] This approach to critique is unique to Deleuze's philosophy in general and is where Nietzsche's influence on Deleuze is most clearly apparent (see: (Deleuze, 2006)).

[7] Notice that 'I remember' is a fifth faculty which is only mentioned as loosely belonging in the fourfold structure of recognition (e.g., in p. 133 and 145) and is not related to in the sentence which follows. Of course the symbolic cross with four branches have a central meeting point: whatever is recognized must already be given in memory. This so called arithmetic error fits well within Deleuze's experimental approach.

as well as form from substance. The use of strong metaphors and unconventional even surprising connections is made in order to break away with dogmatic thought patterns and associations and suggest an experimental and often disruptive perspective. With this, Deleuze offers an additional subversive, ‘underground’ dimension to his critique which is *palpable* and unmediated, very unlike the ‘mainstream’ analytical and intellectually graspable form based on representation. It is expressly made to affect and disturb the otherwise removed position of the thinking subject from the object of thought. As will be discussed later, it is a method that may prove advantageous to complexity thinking where representation-based methods of description fail.

Following this course of criticism, it appears that thinking under the dogmatic image is complacent –“a thought which harms no one, neither thinkers nor anyone else”, and impotent – “incapable of giving birth in thought to the act of thinking”. Taking a more holistic view of thinking, it is evident that the image provides for thought a frame of consistency and stability. It preserves what already exists but lacks the powers of creation. Turning back to the question from the beginning of the chapter, how thought begins, it becomes clear that the image of thought is not and cannot be a beginning. Thought as recognition deals only in end-products. Only the already given (and therefore banal) can be recognized and appear in such thinking. The birth of thought seems therefore to take place beyond representation and beyond the realm of ’what everyone knows and no one can deny’.

2.4 Thought sans Image

Can there be thought sans image? The quote from the Diamond Sutra opening this thesis makes the uncanny claim that the production of unsupported thought is the privilege of great beings[8]. From the words of the ancient text: “a thought unsupported by sights, sounds, smells, tastes, touchables or mind-objects” it is easy to draw a parallel to thought sans image. As already hinted above, Deleuze’s answer reaffirms the singular nature of thought as reflected in the words of the Buddha. For Deleuze, only thought sans image can be seriously considered as thought: “The conditions of a true critique and a true creation are the same: the destruction of an image of thought which presupposes itself and the genesis of the act of thinking in thought itself.” (ibid., p. 139) Again, a strong and uncanny parallel can be found between Deleuze’s destruction of the image and the Buddha’s destruction of illusion. Additionally, two important connections are apparent here. The first is the connection Deleuze claims between critique and creation, in that they share the same conditions. The second is that creation also involves destruction and in this sense destruction is not negative.

[8]Liberated compassionate beings released from illusion, suffering and the cycle of life and death.

What does the destruction of the image amount to? According to Deleuze, the two primary presumptions that hold the image together must be given up. The first is the fitness of each and every faculty for its function:

> "There is no philia which testifies to a desire, love, good nature or good will by virtue of which the faculties already possess or tend towards the object to which they are raised by violence, and by virtue of which they would enjoy an analogy with it or a homology among themselves. Each faculty, including thought, has only involuntary adventures: involuntary operation remains embedded in the empirical." (Deleuze, 1994, p. 145)

The second is the element of common sense that presumably integrates and coheres the operation of the various faculties into a single representation in thought that corresponds to a single object in the world. Nothing of the sort is taking place in thought sans image. The operation of the faculties is discordant and unharmonious. Coordination may arise occasionally as a product, but not as a necessary initial condition:

> "The very principle of communication, even if this should be violence, seems to maintain the form of a common sense. However, it is nothing of the sort. There is indeed a serial connection between the faculties and an order in that series. But neither the order nor the series implies any collaboration with regard to the form of a supposed same object or to a subjective unity in the nature of an 'I think'. It is a forced and broken connection which traverses the fragments of a dissolved self as it does the borders of a fractured I. The transcendental operation of the faculties is a paradoxical operation, opposed to their exercise under the rule of a common sense." (ibid., p. 145)

It remains to clarify (or at this stage at least to outline) how the destruction of the image and the genesis of thought coincide. In what is perhaps one of the key insights that inspired this thesis, Deleuze writes:

> "Something in the world forces us to think. This something is an object not of recognition but of a fundamental *encounter*. What is encountered may be Socrates, a temple or a demon. It may be grasped in a range of affective tones: wonder, love, hatred, suffering. In whichever tone, its primary characteristic is that it can only be sensed. [...] It is not a quality but a sign. [...] It is not the given but that by which the given is given. It is therefore in a certain sense the imperceptible [insensible]. (ibid., pp. 139-140)"

A third parallel can be found here with the ancient text quoted at the beginning of the introduction: "And that which is true perception, that is indeed no perception." Of course the parallels highlighted here are a matter of interpretation and are drawn across vast distances, historical, cultural, philosophical and linguistic. Nevertheless they reflect, at least to some extent, the perennial nature of the problem at hand. Initially there is no 'something' and no 'world' it belongs to. There are no 'us' (in the sense of *a priori* existing thinking subjects outside the world of objects) that are forced. These are all figurative objects that fall short of describing a thought naked of its image. The world, the object of thought and thinker are brought forth in thinking and there are no *a priori* categories that delineate what constitutes an 'object', a 'world' or a 'thinker'. Thinking sans image is a pure *becoming* and, as will be further argued in chapter 6, all becoming is thinking. This is why the 'encounter' is, metaphysically speaking, fundamental.

The fundamental encounter Deleuze writes about is that same event of cognition related in the introduction. It is an uncommon encounter with the unknown and unrecognisable where sense is brought forth from non-sense. It is the nature of this event and its extent which is explored in this thesis. The operation of thought sans image is described by Deleuze as forceful, violent, non-harmonious and even harmful to the thinking subject. From the perspective of the image of thought and the thinking 'I' at its centre, the encounter is a shock or disruption that never fits the existing order and is therefore a threat to its stability and continuation. Thought sans image is harmful precisely in the following sense: a real genuine thought will never leave the thinker intact and as such it is reflexively resisted[9]. Nothing is given *a priori* in thought sans image: neither objects that while perceived are already recognizable, nor the thought-producing machinery reflected by the image of thought. And most notably, the subject of thought, the self as a coherent and coordinated entity under the operation of a common sense, is not given. Thought sans image is truly paradoxical as it goes beyond 'doxa' (what is commonly accepted as given). Contrary to the conventional understanding of paradox as something that does not make sense, thought sans image is paradoxical *because* it is the only operation of *making* sense out of non-sense.

2.5 Discussion

Introducing the image of thought and its critique provides both a starting point and direction to the philosophical exploration aiming to break with the classical ontology of the object. Object-oriented, identity-based ontology is traced to its roots in a presupposed image of thought, in the idea of representation and the model of recognition. Through this tracing, the major weaknesses of seeing the world in terms of identities are exposed. The problem of how thought begins is transformed in the course of this development into the problem of thought sans image. It is quite clear that thought sans image is alien to anything commonly considered as thought if only

[9]The cybernetic principle behind this will be further clarified in the second part of the thesis (see 9.4.1).

because it cannot be mediated by concepts or anything recognizable. But the so-called ’elephant in the room’ here is definitely the metaphysical attack on the ‘I’ and its presumed integrity in the image of thought. To put it boldly, thought is either a transformative operation radical in its implications or a complacent self-preserving, self-affirming and mostly impotent occupation.

There is an additional yet critical nuance having to do with metaphysical thinking itself: that which forces thought “is not the given but that by which the given is given.” An ontological investigation by its very nature always aims to uncover the given, the so-called axiomatic basis upon which a whole structure of knowledge and understanding can be built. Thought that precedes its own image (and its own concept), which can be truly considered a beginning, cannot be a given. It cannot be presupposed, and neither can any other ‘non-thought element’ that precedes thought be presupposed without somehow conceptualizing it *a priori*. In other words, there can be no preceding ontological element at all! The very idea of an ontological basis – the given, is criticized by and replaced with what Deleuze terms a fundamental encounter. It is this nuance that signifies a metaphysical paradigm shift: from ontology to ontogenesis, from being to becoming, from products to the productive and from individual identities to a process of individuation. This is what thought sans image is all about.

At this point, the problematic nature of the term (or rather the sign) ‘encounter’ starts to unfold. Left as it is, it cannot mean much, if anything at all. Conceptualizing it, on the other hand, will merely replace one image with another, or worse yet, throw it back into the embrace of the image it tries to escape. What can be done therefore is only to make palpable the tension and difficulty it invokes. This is what Deleuze means by “it can only be sensed”. Formless as it may be, it is the very force that brings forth thought. The next three chapters (3-5) present the development or rather evolution of a metaphysical system that provides the ground and the distinctive sense of the fundamental encounter at the beginning of thought, based mostly on the works of Bergson, Simondon and primarily Deleuze[10]. Though these works hold between them a complex system of relations and influences, each presents a unique phase in the evolution of metaphysical thinking beyond the image of thought. The chapters are not written and should not be read as an attempt to provide a closed final answer in the form of a single overarching perspective that neutralizes the difficulties, relaxes the tensions and brings everything back to the ‘safe’ centre of the recognizable, object-oriented conventional thought. Rather on the contrary, they are written to make the problematics of the encounter more palpable and the tensions it invokes more acute. It is an attempt to adopt a more experimental approach that emphasizes a productive process rather than a product.

[10]The revolutionary paradigm shift did not start with Deleuze but he definitely epitomizes it.

Chapter 3

Thought and the Idea of Virtuality

In search of the origin of thought, chapter 2 introduced the image of thought and its limits and redirected the search towards thought sans image and the fundamental encounter – the event of cognition that brings forth the recognizable forms of thought as its products. Henri Bergson's philosophical oeuvre is pivotal to the understanding of this event at the origin of thought and from its immense depth and elegance, this chapter will highlight only the major contributions instrumental to the development of this thesis. The primary contribution explored is the idea of virtuality, and how the virtual and actual dimensions of thought constitute its metaphysical ground. This will not only shed light on thought sans image, which was perhaps left somewhat obscure at the conclusion of the previous chapter, but also reframe thought from being a cognitive-psychological process to being a metaphysical process.

3.1 Bergson's Method of Intuition

In *Introduction to Metaphysics* (Bergson, 1946), Bergson makes a fundamental distinction between two kinds of knowing. The first, conventional one, he calls relative knowing as it arises from a relation between an object of knowledge and a knowing agency. This kind of knowing is acquired by adopting a certain perspective in regard to the object and is therefore partial. From its start relative knowing is mediated by the image of thought, as it already presupposes separation between knower and known. In contrast, the second kind of knowing is called absolute knowing. It is acquired under special circumstances where the object of knowledge and knower are not separated. No specific perspective is possible or necessary and therefore the knowledge acquired is complete and absolute. Non-separation implies knowing which is unmediated by the image of thought and therefore of special interest in the context of this thesis. In Bergson's terminology, the first kind of knowing is called *analysis* and the second one *intuition*:

> "It follows from this that an absolute [knowing] could only be given in an intuition, whilst everything else falls within the province of analysis. By intuition is meant the kind of intellectual sympathy by which one places oneself within an object in order to coincide with what is unique

> in it and consequently inexpressible. Analysis, on the contrary, is the operation which reduces the object to elements already known, that is, to elements common both to it and other objects. To analyze, therefore, is to express a thing as a function of something other than itself. All analysis is thus a translation, a development into symbols, a representation taken from successive points of view from which we note as many resemblances as possible between the new object which we are studying and others which we believe we know already." (Bergson, 1946, pp. 7-8)

Clearly this description of analysis pretty much fits representation and the model of recognition described in chapter 2. Analysis as a method of knowing facilitates all object-oriented mediated thinking, all conceptual thinking and by implication everything expressible in language. Without analysis, Bergson notes, language, social life and any other complex form of coordination are impossible.

> "Consciousness, goaded by an insatiable desire to separate, substitutes the symbol for the reality, or perceives the reality only through the symbol. As the self thus refracted, and thereby broken to pieces, is much better adapted to the requirements of social life in general and language in particular, consciousness prefers it, and gradually loses sight of the fundamental [intuitive] self" (Bergson, 2001, p. 128)

Though from the start Bergson proposes that intuition may be applied to any object whatsoever (see above) with what he calls 'intellectual sympathy', this term finds its grounding (and intuitive example) in the way a person knows her own states of consciousness:

> "The inner life is all this at once: variety of qualities, continuity of progress, and unity of direction. It cannot be represented by images. But it is even less possible to represent it by concepts, that is by abstract, general, or simple ideas. It is true that no image can reproduce exactly the original feeling I have of the flow of my own conscious life. But it is not even necessary that I should attempt to render it. If a man is incapable of getting for himself the intuition of the constitutive duration of his own being, nothing will ever give it to him, concepts no more than images." (Bergson, 1946, pp. 15-16)

Heterogeneity, indivisibility (non-reduction) and mobility ("[I]n the human soul there are only *processes*." (Bergson, 2001, p. 131)); these are the elements of thought prior to any representation or conceptualization. In other words, intuition by which one's inner life is captured transports us beyond the realm of representation and into the realm of thought sans image[1]. It is not that representations, distinctions and

[1]What makes the idea of intuition even more interesting is that these very characteristics (whose detailed nature is discussed shortly), are also characteristic of complexity thinking in general. Therefore, by hypothesis, Bergson's method of intuition might prove to be highly relevant if not central to complexity thinking.

concepts are absent from conscious life, as one often conceptualizes psychological states (e.g., in one's ongoing inner dialogue, in planning, etc.), but these conceptualizations draw from a ground that precedes them and in relation to which they will always remain partial and inadequate. Furthermore, while knowledge given to intuition can be decomposed (and simplified) to yield analytical knowledge, intuitive knowledge can never be reconstructed from analytical knowledge, no matter how rich and detailed it would be:

> "The very idea of reconstituting a thing by operations practiced on symbolic elements alone implies such an absurdity that it would never occur to any one if they recollected that they were not dealing with fragments of the thing, but only, as it were, with fragments of its symbol." (Bergson, 1946, p. 28)

and again elsewhere:

> "*it is clear that fixed concepts may be extracted by our thought from mobile reality; but there are no means of reconstructing the mobility of the real with fixed concepts.* Dogmatism, however, in so far as it has been a builder of systems, has always attempted this." (ibid., p. 68)

Bergson criticizes both empiricism and rationalism as merely variants of the analytical method. Being that, their competences as methods of knowing are confined to analysis – what is made possible by the image of thought and cannot possibly replace intuition, which is superior to both (ibid., pp. 25-45). Still, while Bergson treats intuition as an all-encompassing method of knowing, up to this point it appears to be entirely confined to the realm of psychic states. It remains unclear how (if at all) 'intellectual sympathy' is to be deployed beyond one's own conscious states and consequently it leaves the proposition of intuition beyond the psychological speculative (see (Bergson, 1991, pp. 75-76)). The complex path that leads from the psychological to the metaphysical in Bergson's method is addressed next (but see especially 3.4).

3.2 Bergson's Metaphysics

The dichotomy between intuition and analysis goes much deeper and is one of the cornerstones of Bergsonian metaphysics. Bergson's metaphysical system, it will be shown, is full of dualisms: duration-space, quality-quantity, heterogeneity-homogeneity, matter-memory and two kinds of multiplicity, to name a few. But these only prepare the ground for a more profound unity. As Deleuze reflects: "Dualism [in Bergson's philosophy] is therefore only a moment, which must lead to the reformation of a monism" (Deleuze, 1991, p.29). The 'moment' mentioned here is not temporal but a turning point in the development of a whole metaphysical system. This metaphysical turning point, it will be shown, is inherent in the event of cognition that gives birth to thought.

3.2.1 Bergson's Cognitive Theory

Bergson's understanding of thought and the mind starts from a deceptively simple and seemingly familiar cognitive theory. The primary proposition of the theory is that the body (or the cognitive agent) is a centre of action (Bergson, 1991, pp. 17-76). Located in a space along with all other material bodies, the body, and more specifically the brain, is busy with perceiving impressions and producing in response actions that are guided by its interests (e.g., survival, procreation, acquisition of resources etc.). Simple bodies are always affected and affect all other bodies automatically in all possible ways, where by 'automatically', Bergson means a mechanical response necessitated by the laws of physics that apply to all matter. Cognitively able embodied agents, in contrast, filter only those affects of other bodies that are relevant to them according to their interests and act in response only to this reduced set of affects, and where the choice of response is again guided by their interests. At the outset, perception makes available to the agent only those aspects of other bodies that are within the agent's capabilities and interests to respond to. In this sense, the sole function of perception is to facilitate action; it has no extra functions such as the acquisition of knowledge per se (see Bergson (ibid., pp. 20,21,28-30,34,56-57)). "[T]he brain appears to us to be an instrument of analysis in regard to the movement received and an instrument of selection[/determination] in regard to the movement executed."

A fundamental difference between cognitively able embodied agents and other bodies is that they do not act automatically like simple bodies responding at once in all possible ways to the affects they perceive. Instead, there is a gap – a "zone of indetermination" between perception and action that allows a choice of an appropriate response out of a set of available possibilities[2]. There is nothing mysterious in this gap. It is only an alternative way of saying that both perception and action are adaptively filtered and this filtering is guided by certain interests or directives (ibid., pp. 37-43). Whatever belongs to action *defines* the present moment and is *actual*. Perception though being an aspect of action precedes action and in this sense is *not* actual (see 3.2.2 ahead).

The second proposition of the theory is to do with the nature and function of memory (ibid., pp. 77-177). It goes like this: into the gap between perception and action, the whole of the agent's memory – its past experience – is recruited via a complex process to participate in the determination of action[3]. This process of recruitment is termed by Bergson *recollection*:

> "That this is the chief office [function] of consciousness in external

[2]As will be clarified shortly there is no concrete set of available possibilities. At the moment, this should be read only figuratively.

[3]Recent cognitive theories actually invert the respective roles of perception and memory. Using memory, the brain produces an ongoing stream of predictions of the next action while perception only introduces error-correction signals to these predictions.

> perception is indeed what we may deduce a priori from the very definition of living bodies. For though the function of these bodies is to receive stimulations in order to elaborate them into unforeseen reactions, still the choice of the reaction cannot be the work of chance. This choice is likely to be inspired by past experience, and the reaction does not take place without an appeal to the memories which analogous situations may have left behind them. The indetermination of acts to be accomplished requires, then, if it is not to be confounded with pure caprice, the preservation of the images perceived." (ibid., pp. 64-66)

The nature of memory that Bergson has in mind is far from the conventional depiction of a movie-like sequence of distinct, well formed, episodes or events making up the history of the agent's past interactions. Neither it is a lexicon of encoded 'situation $\rightarrow$ proper response' pairs. Bergson's understanding of memory is quite profound and, being essential to his metaphysics, is discussed in detail shortly. For now, suffice to say that at every moment and based on the present perception, consciousness progressively reforms the highly fluid and complex 'stuff' of memory into a concrete pattern that inserts itself into the gap just mentioned and there memory assumes an active role in determining the proper present action (for a detailed description see for example: Bergson (ibid., pp. 103,125-128,149-153 and 166-172)). In other words, the whole of memory – the agent's past – becomes actualized (i.e., involved in action) at *every* present moment. As a first approximation this progressive reformation process that memory undergoes is analogous to a selective compression and feature extraction process informed by immediate perceptions.

For Bergson both perception and memory are given as intuitions, each an unmediated rendering of an independent metaphysical dimension of reality – matter and memory:

> "It is indisputable that the basis of real, and so to speak instantaneous, intuition, on which our perception of the external world [matter in space] is developed, is a small matter compared with all that memory adds to it. Just because the recollection of earlier analogous intuitions is more useful than the [present] intuition [given in perception] itself, being bound up in memory with the whole series of subsequent events and capable thereby of throwing a better light on our decision, it supplants the real intuition of which the office is then merely - we shall prove it later - to call up the recollection, to give it a body, to render it active and thereby actual." (ibid., p. 66)

Here, we are already given a hint as to the synergistic functions of perception and recollection operating on the dimensions of matter and memory respectively.

3.2.2 Duration and Materiality

While conventionally we think of memory as somehow encoded in the neurological structure of the brain, Bergson goes a long way to argue for an entirely different and at first sight astonishing proposition: memory *is not* encoded in the brain. Memory – the past per se, what Bergson terms *duration*, exists independently of space-bound matter and constitutes an independent metaphysical dimension. Not only that, while conventionally we think of the past as following the present, or as a sequence of presents that pass one after the other, the past as duration coexists with the present. In other words, the present and duration are contemporaneous! If this were not the case, it is argued, the past could not possibly be recruited as a whole to participate in the determination of action at every moment as described above. The part of duration that is actualized at every moment by inserting itself into the gap between perception and action is just the very tip of a temporal iceberg (see ahead: 3.3.2). The rest of duration – the whole of the past that coexists with the present but does not participate in it exists in what Bergson terms a *virtual state*. Virtual because it does not partake in the determination of action at present and therefore not actual. Most importantly, the virtual, what remains at every moment apart from actualization, lacks any causative powers as it cannot directly induce actual changes.

The virtual is formless yet not in the sense of lacking form but rather in the sense of having no distinct form, of being a unity of infinite inseparable forms. It is best described as both indivisible and heterogeneous (see 3.3.2 ahead). The images, episodes, and movie-like depictions as well as any other distinct mental formations such as concepts, structures etc. that appear in one's mind are extracts already brought from duration (the virtual dimension) into the actual dimension by the operation of recollection. Such concrete mental states, though not being products of physical activity external to the embodied agent, are still products of mental activity taking place in that agent's brain. As such they all belong to the actual dimension having to do with material changes.

Just as perception presents a relevant state of affairs in space – the material dimension, so recollection presents a relevant state of affairs in duration – the memory dimension (which exists independently of the agent's physical embodiment). From the perspective of duration, the present is a point of convergence of whatever can be usefully applied from memory towards determination of action. From the perspective of space, the present is rendered by perception as everything that is given to be acted upon. Both recollection and perception, given prior to action are therefore virtual (see e.g., (Bergson, 1991, pp. 57-58,67,69,75,82-83,106)). When Bergson didactically separates perception in relation to space from recollection in relation to duration, he uses the terms *pure perception* (ibid., p. 34) and *pure recollection* (ibid., pp. 75,125,238) respectively. In the final chapters of *Matter and Memory* he develops their synthesis (ibid., pp. 243-249). It is the actualization (determination of action) of both perception and recollection brought together ("recollection thus brought down is capable of blending so well with the present perception that we cannot say where perception ends or where memory begins.") that makes the present act itself out and pass into the past. While conventionally the past is considered to pass and the present always *is*, in Bergson's thought it is the other way around: the present *is not*, it is a pure *becoming*, while the past does not cease to be. It *is*, though it remains useless and inactive (Deleuze, 1991, p. 55).

To summarize: perception – bringing forth what can be acted upon in the material dimension, attracts from duration (via recollection) what can be relevant to determining action at present. Melded into each other, perception and recollection bring into form that which can relevantly determine action. This progressive movement from the causally sterile virtual into the actual is termed becoming or actualization. As the virtual becomes actual, contemporaneously the present moment passes into the virtual: it is dissolved into that indivisible heterogeneity of duration as a new present instant follows. The brain/mind of the thinking agent is a convergence point of perception and recollection, of space and duration – the two metaphysical dimensions that together constitute reality. It is a dualism made anew every moment into unity as the virtual becomes actual and the actual dissolves into the virtual. This is in a nutshell the foundation of Bergson's metaphysics. Here we get a first glimpse as to the nature of the event of cognition – the fundamental encounter hypothesized by Deleuze that forces thought to be born: it is the event of the virtual becoming actual; the synthesis of perception and recollection, matter and memory; a metaphysical transformation immanent in every moment. Though admittedly still vague, the event is made somewhat more palpable.

Notes

Before delving further into this fascinating metaphysical theory and making the event of cognition more graspable, it is important for the sake of completion and coherency to mention the following points:

1. Notice that the concept of recognition as Bergson develops it is different from how it is described by Deleuze in the image of thought (see chapter 2). While there recognition requires a distinct object *a priori* given in memory, Bergson hypothesizes two kinds of memory:

   > "[T]he practical, and, consequently, the usual function of memory, the utilizing of past experience for present action - recognition, in short - must take place in two different ways. Sometimes it lies in the action itself and in the automatic setting in motion of a mechanism adapted to the circumstances; at other times it implies an effort of the mind which seeks in the past [i.e., duration], in order to apply them to the present, those representations which are best able to enter into the present situation." (Bergson, 1991, p. 77)

The second aspect of recognition – that which "seeks the past" is a formative process bringing forth a distinct mental object from an unformed virtual state. What makes it re-cognition is the fact that its source is duration as a whole.

2. The proposition that memory is not encoded in the brain might seem to stand in disagreement with the findings of modern neuroscience (not available to Bergson at his time) that generally speaking memory is stored in the brain. The disagreement, however, is only apparent. Bergson makes a clear distinction (see note 1) between experiential memories and other fluid patterns that are subject to change, on the one hand, and so called procedural memories (acquired skills), information patterns and other conditioned behavioural patterns on the other. Memories of the latter category, according to Bergson, are more or less hardwired in the neural structure of the brain. In this his theory agrees with modern neuroscience. The first category, inasmuch as it includes already formed episodic memories, images, and other retrievable patterns, belongs to actualized content that is accessible in one's brain/mind only once the memories and images etc. are actualized, neither before nor after. The important point here is that such actually retrieved content does indeed have corresponding neural correlates in the brain. But these correlates are only complexes of temporary excitations of neuronal circuits that do not stand as evidence that the said actual content is indeed permanently stored in structure. Retrieval and storage are not one and the same function. The unformed virtual content of duration is not and actually cannot be encoded in the brain. It is a well established fact that with a carefully designed stimulus (perceptions) persons can be induced to recollect from their memory fabricated events that never actually took place[4]. The number of such possible fabricated recollections is indefinite because it is no longer confined by actual happenings in the person's past and it can hardly be the case, if at all, that an indefinite number of such recollections can be *a priori* structurally encoded in the brain's limited neural structure. Put differently, the brain's capability of recollection is indefinitely greater than its storage capacity. There is nothing mysterious about this observation though. It only means that dynamic material configurations can produce behaviours that are not determined by structure alone.

3. At this point of the discussion the question remains how exactly this dualistic theory of space and duration applies to all and everything and not only to cognitively able embodied agents. The full appreciation of the theory as a metaphysical theory is yet to be discussed (see 3.4).

[4]See Deleuze's discussion of reminiscence (Deleuze, 1994, pp. 84-85), and also (Porter, Yuille, and Lehman, 1999).

3.3 The Features of Duration-Space Duality

The root of duration-space duality is in how things and states differ and how they compare to each other. It is all about change and the way change appears. Duration and space are hypothesized as metaphysical dimensions of change, that is to say that all differences (and similarities) appear either as differences in space (extended material bodies) or in duration (unextended qualities). Differences that appear in space are quantitative in nature and are always given in terms of 'more' or 'less', while differences and relations that appear in duration are qualitative and are given in terms of kinds.

The fundamental difference that stands between quantity and quality is initially given in a psychological-cognitive sense. Here, exploring its deeper features, it will become clear that it is a metaphysical difference that goes beyond the psychological (see also: (Deleuze, 1991, pp. 34-35)). Clearly, such difference cannot belong to either of the dimensions it spawns. But as Bergson's metaphysical scheme unfolds, it becomes clear that quantity and quality are but extremes of a single continuum. This duality, as was already mentioned, hides a profound unity.

3.3.1 Quantity and Space

The idea of quantity is quite simple when it comes to physical bodies extended in physical space. Extended bodies have volume and if one body X is said to contain (or be contained) by another body Y, it can be said that X and Y hold between them a relation of size being that X is more or less big than Y. This idea can easily be abstracted using sets and relations between sets. Consider X to be a set of N_x elements (discrete or continuous) and similarly Y to be a set of N_y elements. If every element of Y is also found in X,Y is said to be contained in X and there is a clear sense to the proposition that X and Y differ in quantity and one is larger than the other. For example, take the case we started with: extended physical bodies are no more than sets of geometrical points. Using sets, the idea of simple extension and containment relations can be abstracted too. Mathematical *measure theory*[5] shows how sets and subsets can be assigned with abstract numeric values called *measures*. The relation between a set and its measure follows a number of simple axiomatic rules that ensure that the measure of a set always behaves exactly as one would expect extensity to behave. For example, if set Y is contained in set X (i.e., Y is a subset of X) its measure will always be less than the measure of X. Once sets are assigned with measures they can be compared quantitatively and have quantitative relations. If physical space is just the feature of extensity of physical bodies (i.e., it does not exist for itself), the idea of measure allows the conception of abstract space for which all spaces including the physical are but particular cases. And of course abstract space can be populated by abstract bodies.

Abstract spaces have a number of important additional features:

[5]For details see: https://www.encyclopediaofmath.org/index.php/Measure

Homogeneity – By definition, all the bodies that populate space and are related in quantitative relations via their extensity in that space use the same measure assignment. In other words, it is the space that defines the measure of everything that occupies it and in that sense it is homogeneous. For things to be quantitatively comparable they must have something in common – a measure.

Immobility – A measure can be assigned only under the condition of *immobility*. A quantitative relation therefore can be established only between bodies which are immobile (identities). A mobile body means that in terms of its representative set, elements of the set may appear and disappear. Consequently its measure cannot be determined[6].

Simultaneity – In order to relate bodies quantitatively they need somehow to be present simultaneously. For if one of them were to disappear once the other appears, if they were not to share the same space simultaneously, if only for a single instance, they could not possibly be compared.

Distinctiveness – Extended bodies are just sets of elements (e.g., geometrical points) that can be assigned a measure. Using the terminology of sets, extended bodies must be distinct where by distinct it is meant that an element of a set cannot both belong and not belong to the set for if this was the case, a measure could not be assigned and extension would have no meaning.

Divisibility – An extended body as a distinct set of elements can always be divided into distinct subsets contained in it – that is, a number of extended bodies smaller in measure that together constitute the whole (or part) of it[7]. If extension would not necessarily imply divisibility, a multiplicity of distinct bodies would not be possible (see next) and therefore no comparisons of measure could have been performed.

Discrete Multiplicities – whenever bodies are placed in quantitative relations with one another, simultaneity and distinctiveness necessitate that they form a *discrete multiplicity*. Discrete multiplicity is exactly synonymous with the case of a number of bodies (elements) distinctly and simultaneously placed in space so that their measure can be compared. But there is an additional important nuance here. Even when a body is compared to one of its parts, or more generally when two overlapping parts (i.e., sets sharing some of their elements) are compared, at the moment of comparison, being distinct, they are as if placed in space one beside the other so that one is entirely external to the other. The kind of relation held among the elements of a discrete multiplicity is defined

[6] Of course averages can be defined as measures under certain conditions but defining such a measure merely defines a space where the mobile aspect is eliminated.

[7] Notice the exotic case of atomic bodies that are sets of a single element. Such bodies are still extended but indivisible. Still, this property holds as a few of such bodies can be compounded into a bigger divisible body. If there was only a single atomic body there would have been no meaning to quantitative relations because there was nothing to relate it to.

as *relation of exteriority*, as the elements are necessarily exterior to each other. Space itself separates the bodies being related. The reason for that is inherent in what has already been said. The measure of the body (the space it occupies), is always assigned to it in its ultimate distinctiveness i.e., taking into account only the elements that constitute the body. So even if Y is entirely contained within X, the measure of X and that of Y are taken as if they form entirely separate bodies exterior to each other in this respect.

This description captures most of the important features of space developed by Bergson in the second chapter of *Time and Free Will* (Bergson, 2001, pp. 75-139) though with a somewhat more concise and cleaner terminology[8]. There are, however, a couple of additional points that merit attention when space is given in thought. The first point is that extended bodies in space are conceived by the mind both as unities and multiplicities: "[W]e shall see that all unity is the unity of a simple act of the mind, and that, as this is an act of unification, there must be some multiplicity for it to unify." (ibid., p. 80) After a somewhat overly complicated discussion Bergson reaches the following significant conclusion:

> "[T]here is no change in the general appearance of a body, however it is analyzed [divided into parts] by thought, because these different analyses, and an infinity [infinity only in the case of continuous sets] of others, are already visible in the mental image which we form of the body, though they are not realized: this actual and not merely virtual perception of subdivisions in what is undivided is just what we call objectivity. It then becomes easy to determine the exact part played by the subjective and the objective in the idea of number [Bergson uses numbers as abstract extended bodies]. What properly belongs to the mind is the indivisible process by which it concentrates attention successively on the different parts of a given space; but the parts which have thus been isolated [multiplicity] remain in order to join with the others [simultaneity], and, once the addition is made [and the multiplicity is unified into a body], they [the resulting body] may be broken up in any way whatever. They are therefore parts of space, and space is, accordingly, the material with which the mind builds up number [or any extended body], the medium in which the mind places it." (ibid., p. 84)

Extended bodies, as they appear in thought, have an infinite number of possible divisions (given a continuous measure) into multiplicities that are virtual (not realized). When a body is analysed into a concrete actual multiplicity, it is objectified – it is an object made of actual parts. Its virtual divisibility is made an actual division. All this while the general appearance of the body did not change. What is subjective

[8] A further important refinement of the metaphysical meaning of space is discussed in 3.4.1.

and given to intuition is a unity virtually divisible. What in contrast is given to analytic thought is already an actual multiplicity in space. It is the projection into space *in thought* that transports a body from intuition to analysis.

But there are obviously aspects in thought that cannot be directly objectified i.e., projected into extended space:

> "The case is no longer the same when we consider purely affective psychic states, or even mental images other than those built up by means of sight and touch. Here, the terms being no longer given in space, it seems, a priori, that we can hardly count them [subject them to quantitative analysis] except by some process of symbolical representation." (Bergson, 2001, pp. 85-86)

Which brings us to a second significant point: the case where it is possible by means of symbolic representation to project into space and bring into quantitative relations aspects of the mind that are essentially not extended. Remarkably, symbolic representations and conceptualizations possess many of the features of extended bodies: they are immobile, distinct and simultaneous and can therefore form discrete multiplicities. Since the operation of symbolic representation does not fully comply with the defining rules of measure, the sense of them being divisible and homogeneous remains vague though. In as far as symbols can somehow be grouped together to form other symbols e.g., letters into words, words into sentences, notes into melodies, etc., they possess a kind of finite divisibility, but unless further constraints are introduced, systems of symbols cannot generally hold full quantitative relations. They retain, however, a reduced sense of such relations e.g., whole-part similar-dissimilar relations etc. that allow significant analysis.

Symbolic representation is basically how objects grasped by intuition are reduced to analytical terms (see 3.1). If a well defined measure can be introduced, a full quantitative analysis is possible. In many cases, however, such analysis remains expressly vague. For example, can the mother's love be equally divided among her children? Does she love one more than she love the other(s)? In such examples it is very clear that the symbolic representation produced is qualitatively different from what is represented (see quote in page 39). It is only the representations that are quantitatively related while what they represent remain incomparable. With symbolic representations the metaphysical dimension of space is expanded beyond the so called metric space that facilitates full quantitative relations. It becomes a space of all immobile, distinct and separated objects – the space of actual identities and discrete multiplicities.

A third point, a special case of the second, is the case of linear time:

> "[W]e could not introduce order among terms without first distinguishing them and then comparing the places which they occupy; hence we must perceive them as multiple, simultaneous and distinct; in a word,

> we set them side by side, and if we introduce an order in what is successive, the reason is that succession is converted into simultaneity and is projected into space." (ibid., p. 101)

In contrast to duration, which is discussed next, time in its conventional use is a measure and therefore is a spatial dimension with all the features mentioned above. Changes in mental states that are essentially qualitative can be projected into time and by that gain temporal extensity (e.g., yesterday I was sad but today I am happy, it has been a trying period etc.) – the extent of the time they last. In that, conscious states are made immobile, separated from each other and external one in relation to the other thus forming discrete multiplicities that can be inserted into representable narratives. Some implications of that are discussed in the following.

3.3.2 Quality and Duration

Complementary to extensity – the essential property of anything given in terms of quantity, *intensity* is the essential property of anything given in terms of quality and is unextended. Intensity is assigned to mental states such as sensations, feelings, desires, efforts and other general impressions. Conventionally, intensity describes or compares difference in the strength or magnitude by which a certain state is experienced. For example, I feel very hungry, I think hard, I am less tired, I am more optimistic, my desire for her is overwhelming, etc. At first sight, it seems that intensity thus applied shares similar features to a quantitative measure. But this is not the case. Bergson dedicates the first chapter of *Time and Free Will* (ibid., pp. 1-74) to refute this notion and establish that whenever the term intensity or intensive difference is applied, it is applied and should be applied only in the sense of indicating qualitative differences. The so called quantitative notion of intensity is only superficial because any division or multiplication of intensity always implies a change in quality:

> "The idea of intensity is thus situated at the junction of two streams, one of which brings us the idea of extensive magnitude from without, while the other brings us from within, in fact from the very depths of consciousness, the image of an inner multiplicity. Now, the point is to determine in what the latter image consists, whether it is the same as that of number (extensity), or whether it is quite different from it." (ibid., p. 73)

Rephrasing the question, while a multiplicity of extended bodies can be quantified, compared and measured, could a similar procedure be applied to a multiplicity of non-extended qualitative mental states? Can a change of intensity indeed be quantified? Bergson's answer is no. Qualitative changes form an independent metaphysical dimension: duration.

The idea of qualitative change (change in kind) and duration is best illustrated in the simple example of the movement of a physical body in space. Bergson distinguishes two aspects in such motion: the first is the obvious spatial one, that is, the trajectory traversed by the moving body. The trajectory is an extended body with all the features mentioned in the discussion about space. The second aspect is the very sense of motion or *mobility* which is given at once in conscious experience:

> "Now, if we reflect further, we shall see that the successive positions of the moving body really do occupy space, but that the process by which it passes from one position to the other, a process which occupies duration and which has no reality except for a conscious spectator, eludes space. We have to do here not with an object but with a *progress*: motion, in so far as it is a passage from one point to another, is a mental synthesis, a psychic and therefore unextended process. [...] If consciousness is aware of anything more than positions, the reason is that it keeps the successive positions in mind and synthesizes them. But how does it carry out a synthesis of this kind? [...] We are thus compelled to admit that we have here to do with a synthesis which is, so to speak, qualitative, a gradual organization of our successive sensations, a unity resembling that of a phrase in a melody. This is just the idea of motion which we form when we think of it by itself, when, so to speak, from motion we extract mobility." (Bergson, 2001, pp. 110-111)

In the synthesis of mobility all the key features of duration are highlighted. Duration is unextended and is populated by qualitative mental states. What takes place in duration is a *synthesis in progress* that unifies a succession of impressions of positions in space into an undivided mental state that intuitively grasps mobility at once. What is unique in mobility is that it *endures* in one's mind as such while its very nature is the change (in this case of positions) internal to it. In mobility one no longer perceives distinct positions in space, but a *succession*. By succession Bergson means a mental dynamic where in every actual state of mind, the states previous to it still persist. But they persist not as separate distinct states but rather as a dynamic organic whole:

> "[...] as happens when we recall the notes of a tune, melting, so to speak, into one another. Might it not be said that, even if these notes succeed one another, yet we perceive them in one another, and that their totality may be compared to a living being, whose parts, although distinct, permeate one another just because they are so closely connected? [...] We can thus conceive of succession without distinction, and think of it as a mutual penetration, an interconnection and organization of elements, each one of which represents the whole, and cannot be distinguished or isolated from it except by abstract thought [symbolic representation]. Such is the account of duration which would be given by a being who

was ever the same and ever changing, and who had no idea of space." (ibid., pp. 100-101)

Duration is the dimension of unextended qualities and its defining feature is enduring qualitative changes. Can these be measured or compared in terms of intensity and if they can, in what sense? To address this question the characteristic features of duration implied by the above quotes need to be carefully specified:

Heterogeneity – Since qualitative states continuously and progressively permeate each other, no actual state is ever identical to any of the previous ones. As each moment passes, it affects all past moments and changes them (see 3.2.2), Yet succession does not cause states to disappear or average each other into a uniform unchanging state. Heterogeneity means therefore a radical state of difference; no state is comparable to any other state.

Mobility – Qualitative states are mobile and duration therefore is pure mobility. As moments pass they change the whole of duration (the past) and the duration in turn will change all subsequent actual moments as it inserts itself into them. Furthermore, if any part of duration is attended to and made separate from duration, it is also immobilized. This is what happens when an aspect of duration is symbolically represented (for another clear description of this point see (Bergson, 1946, pp. 48-49)).

Succession – Past states endure. The whole of the past (duration) is contemporaneous to the present. Concomitantly the actual present as it passes endures in duration (though only virtually).

Non-distinctiveness – States dynamically permeate each other and therefore are inseparable. No state can become distinct of the others unless it is symbolically represented, immobilized and by that projected out of duration into space.

Indivisibility\Holography – The whole of duration is reflected in each and every part of it (see (ibid., pp. 25-27)). When attention moves from the whole of a qualitative state to one of its parts, this attempt of division is already a qualitative change that affects the previous whole and where the previous whole still persists. Duration therefore is an inseparable continuum. To be accurate, it is not that division is impossible, it is rather that any division implies a change of nature of that which was divided. There is no way to recompose a whole that passed from the parts. Each part itself becomes a whole containing everything that has passed.

Qualitative Multiplicities – Qualitative mental states form in duration qualitative multiplicities. A qualitative multiplicity is exactly synonymous to the case of multiple inter-penetrating heterogeneous states (e.g., a bitter-sweet taste, a tragic-comic situation, love-hate relationships etc.). The kind of relation held among the elements (figuratively speaking) of qualitative multiplicity is defined as *relations of interiority*. They are inseparable because being successive, each is always found *inside* any other. A qualitative multiplicity is a complex term; it is neither one nor many. Being mobile, it is always different from itself while it remains itself (Bergson, 1946, pp. 22-25).

No Negation – Since duration is all-inclusive and inseparable, there can be no negation in duration because the negation of anything requires separation, distinctiveness and the immobility of that which is negated. In other words, terms that negate each other always hold a relation of exteriority between them. It is the case therefore that duration is all-affirming and negation can be achieved only by means of symbolic representations.

Figure 3.1: The Taoist symbol of Yin-Yang illustrates a qualitative multiplicity. The Yin and Yang elements are mobile, inseparable, always found within each other and are defined by each other. They hold between them a relation of interiority.

Two points become immediately clear regarding intensity. First, mobility, succession and indivisibility render the idea of simple comparison inapplicable. Duration as a qualitative dimension can only be compared to itself and is always different from itself. Second, heterogeneity and the fact that qualitative states form only a qualitative multiplicity imply that whenever an intensive difference is considered, it can only be considered uniquely. In duration there is no measure that applies homogeneously to all states. Whenever intensity is applied to mean a change in quality, it is unique to that change. In other words, the term intensity is itself heterogeneous and mobile in contrast to extensity, which is homogeneous and immobile. Processes and actions cannot be divided without inducing a qualitative change and therefore they are described as intensive (Bergson, 2001, p. 112). Even in the very simple example of physical movement, to double the intensity of movement (acceleration) requires force and energy, while to double the distance traversed by a moving body (which is extensive) does not require (in the ideal case) extra force or energy.

It is important to note that though duration is the past or memory, it is not organized as a sequence of distinct events with a distinct causal relation between them (see 3.2.1). Therefore, duration is not history. History is only a projection of immobilized moments into a spatial-like dimension of time (see 3.3.1). Also duration is nothing like a space of possibilities surrounding the actual state of affairs, because possibilities are already formed (represented), immobilized and distinct cases, which are actualized as mental states in a mental space, just not in the physical one. Ensembles of indistinct and only partially determined states, i.e., having some probabilistic description, stand in some closer proximity to duration but still are not duration because they are partial to it but a part that does not reflect the whole. Additionally, they cannot be said to be mobile.

Inasmuch as it is difficult to grasp visually, Bergson depicts duration as having the form of an abstract cone (Bergson, 1991, pp. 150-170). The tip of the cone is the actual present moment where the whole of duration is condensed into a single point that inserts itself into the gap in the present moment (see 3.2.2) and together with the immediate perception actualizes the moment. The widest basis of the cone is populated by all the moments that ever passed but in their distinct form, that is, as if they are laid out in space side by side without any organization and without succession i.e., without interpenetrating each other. Between these two extreme points, the whole of duration occupies an infinite number of planes. Each plane is populated by all moments but with a varying degree of interpenetration, from no interpenetration at the bottom (maximally extensive) to infinite interpenetration at the tip point (maximally intensive at the present[9]). Each plane therefore represents a different degree of *contraction* or compression of the whole, and all these degrees exist in the unity of duration – what is also termed *virtual coexistence* (Deleuze, 1991, pp. 51-72). The higher the contraction the less distinct are the features that can be distinguished between states, images, episodes and events but nothing is lost in duration. Moreover, the whole cone is mobile; as it extends into the future, the present tip passes into the past and once it does, it affects all planes that are contemporaneous with it. This abstract model of duration, especially its dynamism, is pretty complex but the following concise description gives a reasonably accurate and clear idea:

> "From this [...] result, at every moment, an infinite number of possible states of memory, states figured by the sections A'B', A"B" [the planes of the cone] of our diagram [the cone]. These are, as we have said, so many repetitions of the whole of our past life. But each section is larger or smaller according to its nearness to the base or to the summit [different levels of contraction]; moreover, each of these complete representations of the past brings to the light of consciousness only that which can fit into the sensorimotor state and, consequently, that which resembles the present perception from the point of view of the action to be accomplished. In other words, memory, laden with the whole of the past, responds to the appeal of the present state by two simultaneous movements, one of translation, by which it moves in its entirety to meet experience, thus contracting more or less, though without dividing, with a view

[9]The actual present moment is indeed the most intensive moment in experience.

> to action; and the other of rotation upon itself, by which it turns toward the situation of the moment, presenting to it that side of itself which may prove to be the most useful. To these varying degrees of contraction correspond the various forms of association by similarity." (Bergson, 1991, pp. 168-169)

The importance of this cone model is not so much in the particular mechanism hypothesized by Bergson but in that it highlights a continuum of degrees of succession and interpenetration which, as will be discussed below, is the key to unifying the duration-space duality. The more moments are isolated from each other and made distinct the more homogeneous they become. This becomes clear with an analogy: when we look at a digitized photo of a face, we grasp the whole image at once as a face with a vast heterogeneity of the details that constitute it. We can then isolate smaller and smaller features in the photo and the smaller the features get the less heterogeneous they become, e.g., we remain with small patches of the photo differing only in shades of colour etc. Eventually the photo is isolated into pixels, each of a single colour – a combination of red, green and blue and then even the colour representations can be further isolated to ones and zeros. The detailed heterogeneous photo is now an homogeneous 3D spatial map of a single quantitative feature: the presence or absence of ones.

No doubt duration as a virtual dimension, even if confined only to the mental states of cognitive agents, gives a glimpse of thought sans image. It is no other than the incessant mobility of the virtual. Its heterogeneity is far from random disorder, but neither it is order as yet. Now one can better appreciate the significance of the idea of reality as a metaphysical meeting point between the virtual and the actual. This meeting point is an essential aspect of the event of cognition that brings forth image out of the image-less, sense out of non-sense and form out of formlessness, or in short, gives birth to concrete thought forms by crossing the apparent impasse between thought sans image and thought as representation (see summary on page 43).

3.3.3 Quality-Quantity, Duration-Space, Virtual-Actual

Duration and space, quality and quantity, the virtual and actual are three facets that constitute reality, each of which is a duality. In the course of the 20th century the reigning scientific worldview consolidated around an image of reality in four dimensions, three of space and one of time. This image is expressly immobile as time is considered only as yet another extensive dimension additional to the three spatial ones. This image is but an extension of the Newtonian deterministic worldview.

The metaphysical theory authored by Bergson introduces into reality a mobile, irreducible and inherently qualitative extra dimension accessible only by intuition. Bergson's worldview endows reality with an indeterministic and creative aspect which is missing from the immobile deterministic worldview. Whereas immobile reality admits only objects of identity, relations of exteriority and change that is always arrested within such objects and relations, mobile reality admits of intrinsic difference, relations of interiority, and pure mobility in the ancient Heraclitan sense (more on this in the following chapters).

The two dimensions of space and duration are continuously permeating each other in an endosmotic process in consciousness. The mobility of duration inserted into the present causes it to pass (see 3.2.2). The immobility of a divided space (see 3.4.1-3.4.2) is encoded into duration:

> "[A]s our ego comes in contact with the external world at its surface; our successive sensations, although dissolving into one another, retain something of the mutual externality [exteriority] which belongs to their objective causes; and thus our superficial psychic life comes to be pictured without any great effort as set out in a homogeneous medium. [...] [A]s the repeated picture of one identical objective phenomenon, ever recurring, cuts up our superficial psychic life into parts external to one another, the moments which are thus determined determine in their turn distinct segments in the dynamic and undivided progress of our more personal conscious states. Thus [...] little by little our sensations are distinguished from one another like the external causes which gave rise to them, and our feelings or ideas come to be separated like the sensations with which they are contemporaneous." (Bergson, 2001, pp. 125-126) (see also quote on page 38).

Every moment of our mental life is both mobile and immobile, both extended and intense, both virtual and actual, only in different proportions. Sometimes thought is flowing without image and more than anything else it is felt as pure qualitative movement. At other times it progresses in distinct consecutive steps, each immobilized, conceptualized and recognized and by that separated from all the rest. It all has to do with the degree by which the moments endure in each other, to which degree the past encroaches on the present and to what extent the present melts into the past as it passes. Not only do the virtual and actual form two extremes of a continuum, but also the various phases of this continuum are continuously confused.

In *Bergsonism* Deleuze further reflects on the profound unity of the two dimensions:

> "What, in fact, is a sensation? It is the operation of contracting trillions of vibrations onto a receptive surface. Quality emerges from this, quality that is nothing other than contracted quantity. This is how the notion of contraction (or of tension) allows us to go beyond the duality of homogeneous quantity and heterogeneous quality, and to pass from one to the other in a continuous movement." (Deleuze, 1991, p. 74)

This newly found unity does not come to neutralize the dualism developed by Bergson. It rather adds to it a complementary aspect suggesting a complex metaphysics that is neither monist nor dualist yet is both. Monism and dualism each in itself simply falls short of offering a satisfying metaphysics. It is this fine borderline, not entirely drawn between them, that provides an access to thought that comes before image. All along we notice that the ideas and the concepts involved are clearly delineated yet remain open and permeate each other. The philosophical method employed demonstrates the very claims it develops.

3.4 A Metaphysics of Change and Self-organization

We are now in a position to discuss the full thrust of Bergson's metaphysics and make a step beyond it. Up to this point duration and the virtual were given as fundamental features of mental states and thought as they appear in the minds of cognitively able agents. Yet, the virtual still presupposes a thinking conscious agent. Here, this presupposition is further investigated to highlight the later developments in Bergson's thought. Space and duration first presented as fields of psychological activity (perception and recollection) are finally developed and refined into all-encompassing metaphysical dimensions. By that, Bergsonian thought is positioned to become a core paradigm of complexity thinking.

3.4.1 Extensity and Divisibility Revisited

In the concluding chapter of *Matter and Memory*, Bergson refines his description of space and its metaphysical significance:

> "But now suppose that this homogeneous space is not logically anterior, but posterior to material things and to the pure knowledge which we can have of them; suppose that extensity is prior to space; suppose that homogeneous space concerns our action and only our action, being like an infinitely fine network which we stretch beneath material continuity in order to render ourselves masters of it, to decompose it according to the plan of our activities and our needs. Then, not only has our hypothesis the advantage of bringing us into harmony with science, which shows us each thing exercising an influence on all the others and, consequently, occupying, in a certain sense, the whole of the extended. [...] [I]f we suppose an extended continuum, and, in this continuum, the center of real action which is represented by our body, its activity will appear to illuminate all those parts of matter with which at each successive moment it can deal. The same needs, the same power of action, which have delimited our body in matter, will also carve out distinct bodies in the surrounding medium. Everything will happen as if we allowed to filter

> through us that action of external things which is real [i.e., applies to interactions with the rest of the universe], in order to arrest and retain that which is virtual: this virtual action of things upon our body and of our body upon things is our perception itself." (Bergson, 1991, pp. 231-232)

The distinction made here, between extensity and divisibility, leaves only extensity as having metaphysical significance whereas divisibility, and consequently measurement, is a later product of cognition. Space as pure divisibility belongs to representation and comes to serve the agent's interests and actions. After this refinement, there is no division in the metaphysical sense, only two continuums: extensity, and intensity. Extensity undivided and without measure is almost like intensity except that it is homogeneous. It allows relations of 'more' or 'less' but these are not translatable to measures without the introduction of space as pure divisibility.

Bergson's metaphysical scheme is now much clearer. It draws a sharper line between duration and space: while duration is virtual, space is not the actual. The actual is what is brought to action in material continuity where space as divisibility is only stretched by the mind beneath this material continuity in order to divide it and immobilize that which it has divided (see also the discussion on symbolic representation in 3.3.1).

Given this refinement Bergson needs to answer yet another problem: what causes the extended continuum of matter to appear in perception as distinct separated bodies? The explanation of this separation is traced back to the body's need and capacity to act (see above: "...the same needs, the same power of action..."). But this is a problematic point: if the knowledge we gain by perception of other bodies is given in intuition, it is by Bergson's own definition absolute knowledge. Such knowledge cannot possibly be conditioned by the perceiver's own perspective, i.e., her needs, powers of action etc.

The problem is resolved by considering the following points: *a*) extensity captured by intuition is a virtual continuum, i.e., like duration it is undivided, indistinct and not yet formed, and *b*) perception is a process analogous to recollection: from a virtual extensity it gradually brings into form (determines) only the aspects of materiality relevant to the actions of the cognitive agent. In other words, it is the process of perception that conditions what initially is not. Thus understood, the description is coherent: pure intuition which differs from perception remains unconditioned by any specific perspective. What is initially given to intuition is the absolute knowledge of other bodies, and this is gradually reduced in perception to knowledge relative to the situation of the cognitive agent. It is only this knowledge that renders other bodies as distinct.

We remain with a few riddles though: in the metaphysical continuum of both extensity and intensity how are the cognitive and non-cognitive delineated prior to representation? Is such delineation even possible?

3.4.2 Mobility First

The refinement in (3.4.1) establishes a metaphysical continuum with two dimensions, extensity and duration. As already discussed in 3.3.3 these are but extreme cases of a single continuum. The next fundamental (and revolutionary) feature of Bergson's metaphysical scheme is mobility[10]. In (Bergson, 1946, p. 75) he clearly criticizes the opposite dogma:

> "That there are not two different ways of knowing things fundamentally, that the various sciences have their root in metaphysics, is what the ancient philosophers generally thought. Their error did not lie there. It consisted in their being always dominated by the belief, so natural to the human mind, that a variation can only be the expression and development of what is invariable. [...]"

Immobility arises from division and representation and is secondary. It is always preceded by mobility, but mobility is preceded by nothing. Static objects, ideas, concepts and relations are thus only superficial constructs. Underneath appearances, in their metaphysical nature, they are mobile. Nowhere is this fundamental mobile nature of reality clearer than in the following:

> "There is a reality that is external and yet given immediately to the mind [intuition]. [...] This reality is mobility. Not *things* made, but things in the making, not self-maintaining states, but only changing states exist [becoming]. Rest is never more than apparent, or, rather, relative. The consciousness we have of our own self in its continual flux introduces us to the interior of a reality, on the model of which we must represent other realities. *All reality, therefore, is tendency, if we agree to mean by tendency an incipient change of direction.* [...] Our mind, which seeks for solid points of support, has for its main function in the ordinary course of life that of representing states and things. It takes, at long intervals, almost instantaneous views of the undivided mobility of the real. It thus obtains *sensations* and *ideas*. In this way it substitutes for the continuous the discontinuous, for motion stability, for tendency in process of change, fixed points [...]" (ibid., pp. 65-66)

Two points are worth mentioning in the context of this quote:

1. The event of cognition gains here an additional sense: it is not only the meeting point of the virtual and actual (see end of 3.2.2), but also a meeting point of the immobile and the mobile. Both the virtual and actual are fundamentally

[10] A question can be raised here as to an apparent contradiction between mobility as universally fundamental and the second law of thermodynamics that predicts the final state of the universe to be immobile and homogeneous (i.e., maximum entropy). But the application of the second law to the universe must be preceded by a presupposition as to whether the universe is an open system or a closed one. Clearly, a fundamentally mobile universe implies that it is open-ended.

mobile. When we immobilize the virtual we conceive of unrealized yet already recognized possibilities. When we immobilize the actual we conceive of actual change as a simultaneity projected in homogeneous time (see e.g., (Bergson, 2001, p. 115)). Though metaphysically mobility precedes immobility, what characterizes the event of cognition is always movement across the meeting point in both directions: from the virtual to the actual, from the actual to the virtual, from the mobile to the immobile and from the immobile to the mobile. The event does not have a preferred direction, inasmuch as it creates, it also dissolves.

2. Mobility is expressly the mark of thought sans image – thought which is unsupported, in the words of the Buddha quoted in the introduction. Interestingly, mobility introduces yet a deeper connection to Buddhist teachings. According to Bergson, representation is the result of the mind seeking for solid points of support: states, things, stable relations, in short, identities. A primary tenet in the teaching of the Buddha is that reality is fundamentally impermanent and the seeking and grasping of permanent states is the root source of all suffering. Bergson's metaphysics of change and the teaching of the Buddha seem to be in full agreement regarding the nature of reality and the superficiality of immobile entities, states and relations. On a parallel line of reasoning, the method of intuition is closely related to producing unsupported thought.

3.4.3 Everything Endures

We have reached now the more challenging point in the development of Bergson's metaphysics. As Bergson's work develops, there is a pronounced shift from duration as a psychological dimension to duration as a metaphysical dimension. In Bergson's early works, duration is only assigned to conscious beings as reflected by the discussion to this point. In *Introduction to Metaphysics*, Bergson clearly states that the method of intuition accesses a metaphysical dimension of reality which is beyond mediation and beyond symbolic representation. Only by the effort of intuition can something be known in an absolute sense:

> "If there exists any means of possessing a reality absolutely instead of knowing it relatively, of placing oneself within it instead of looking at it from outside points of view, of having the intuition instead of making the analysis: in short, of seizing it without any expression, translation, or symbolic representation [i.e., thought without image]-metaphysics is that means." (Bergson, 1946, p. 9)

The metaphysical dimension accessible to intuition is not merely one's own duration. It is a key to accessing other durations and other scales of contraction that reach the point where the "eternity of life" – the movement of the whole universe – can be captured:

> "[...] so the intuition of our duration, far from leaving us suspended in the void as pure analysis would do, brings us into contact with a whole continuity of durations [outside us] which we must try to follow, whether downwards or upwards; in both cases we can extend ourselves indefinitely by an increasingly violent effort, in both cases we transcend ourselves. In the first we advance towards a more and more attenuated duration, the pulsations of which, being rapider than ours, and dividing our simple sensation, dilute its quality into quantity; at the limit would be pure homogeneity, that pure repetition by which we define materiality. Advancing in the other direction, we approach a duration which strains, contracts, and intensifies itself more and more; at the limit [it] would be eternity. No longer conceptual eternity, which is an eternity of death, but an eternity of life. A living, and therefore still moving eternity in which our own particular duration would be included as the vibrations are in light; an eternity which would be the concentration of all duration, as materiality is its dispersion. Between these two extreme limits intuition moves, and this movement is the very essence of metaphysics." (Bergson, 1946, pp. 63-64)

It is not entirely clear, however, whether this metaphysical dimension exists only for embodied conscious agents or whether it exists for all bodies. The power of intuition lies in that since the whole of the mobile universe (eternity) is reflected in every part of it and all moments universally permeate each other and coexist virtually, consciousness touches everything from within and reflects everything.

On this, Deleuze (1991, p. 76) reflects: "We can see that, as in *Matter and Memory*, psychology is now only an opening onto ontology, a springboard for an 'installation' in Being." The move towards the metaphysical is undeniable. But how is this move reasoned? "Installation in Being" requires that things and states exist and endure inherently, that is, independently of a presupposed conscious agent for whom they exist and endure. This requirement does not seem to be in line with how cognition works. Things exist in the perception or memory of a cognitively able agent as to fit (or rather manifest) her interests and tendencies. Immobile things and states exist only for the mind that conceives them and acts upon them (see page 47).

An excerpt from the quote in 3.4.1 is revealing: "The same needs, the same power of action, which have delimited our body in matter, will also carve out distinct bodies in the surrounding medium." It is only the mind that holds things and states in one actual configuration rather than another according to need. In other words, things do not have an independent existence or duration. Can duration be extended to other bodies which are not endowed with cognitive capacities? The answer is not simple. The following quote admits (like the one above) of objects with durations other than ours (the psychological one) and of different scales from ours (superior and inferior) but these durations are still interior, that is, still presupposing a conscious beholder:

> "It would be failing to see that the method we speak of [intuition] alone permits us to go beyond idealism, as well as realism, to affirm the existence of objects inferior and superior (though in a certain sense interior) to us [i.e., objects with durations distinct from ours], to make them co-exist together without difficulty, [...]" (Bergson, 1946, p. 56)

Deleuze identifies a second interpretation: a universal duration with what he terms as *virtual coexistence* of all the levels of the (universal) past:

> "[...] The idea of a virtual coexistence of all the levels of the past, of all the levels of tension, is thus extended to the whole of the universe: This idea no longer simply signifies my [me as a conscious agent] relationship with being [psychological duration], but the relationship of all things with being. Everything happens as if the universe were a tremendous Memory" (Deleuze, 1991, p. 77)

In this interpretation two types of duration are distinguished: a universal duration and psychological durations that only beings above a certain level of complexity are capable of having. Other things endure only for the universe as a whole, or for other agents endowed with psychological duration:

> "If things are said to endure, it is less in themselves or absolutely than in relation to the Whole of the universe in which they participate insofar as their distinctions are artificial. [...] In this sense, each thing no longer has its own duration. The only ones that do are the beings similar to us (psychological duration), then the living beings that naturally form relative closed systems[11], and finally, the Whole of the universe." (ibid., p. 77)

A third interpretation endows an independent duration to all material things. Inasmuch as all material things change, they can be said to have a past that affects their present actuality and hence duration, which can of course be very limited. This finds support in quotes like the following:

> "Only one hypothesis, then, remains possible; namely, that concrete movement [the actual changes things undergo], capable, like consciousness, of prolonging its past into its present, capable, by repeating itself, of engendering sensible qualities, already possesses something akin to consciousness, something akin to sensation." (Bergson, 1991, pp. 246-247)

Also Deleuze (1991, p. 75) notes:

> "Hence, the importance of *Matter and memory*: Movement is attributed to things themselves so that material things partake directly of duration,

[11]Closed systems here can be understood to be closures discussed in the second part of the thesis.

> and thereby form a limit case of duration. The immediate data (*les donées immtidiates*) are surpassed: Movement is no less outside me than in me; and the Self itself in turn is only one case among others in duration."

In summary, the above quotes present three distinct hypotheses as to how duration is extended from the psychological to the metaphysical:

1. Duration is applied to all things but only via the agency of complex beings capable of intuitive grasping (e.g., cognitive agents, living beings and perhaps other systems that undergo qualitative development). Still, such beings must be presupposed.

2. There is one universal duration that all things partake in. Other durations are just limited manifestations which nevertheless reflect the whole through relations of interiority.

3. There is a plurality of independent durations.

The philosophical problematics of the various hypotheses are quite involved and beyond the scope of this work (for a detailed discussion see: (Deleuze, 1991, pp. 73-89)). In simplified terms, we have already discussed in 3.4.1 the problematics of the first hypothesis (which seems that Deleuze have missed). To make such a hypothesis work requires delineating the cognitive from the non-cognitive and the conscious from the non-conscious. Considering the metaphysical continuum of both duration and extensity, there is hardly a justification for such *a priori* delineation. As to the second and third hypotheses, we argue that they are rather limited cases of a more complex hypothesis – *metaphysical self-organization*.

3.4.4 Metaphysical Self-organization

The hypothesis of metaphysical self-organization developed here is not discussed by Bergson but is implicit in his philosophy. It comes to answer two questions. The first is the sense in which duration is metaphysical and the second is how this metaphysical theory brings forth distinct things out of a continuum (see 3.4.1). Notice that though the following discusses only duration, the ultimate unity of duration and extensity, or rather their fundamental non-separation is assumed (see 3.3.3).

Self-organization

The thrust of this hypothesis is that even if we initially consider a universal indivisible duration (second hypothesis in 3.4.3), because it is mobile and heterogeneous, no matter what contingency is involved, aspects of it spontaneously diverge and become more or less enduring in each other, or put otherwise, more or less separated. Consequently, as aspects of duration become more or less separated and form diverse relations of interiority and exteriority, the universal indivisible continuum of duration spontaneously manifests a continuum of material configurations, states and relations with various degrees of immobility and distinctiveness. This is how distinct immobile things spontaneously emerge. Hence self-organization.

By metaphysical self-organization, therefore, we mean *an inherent tendency engendering a productive process*. A tendency of a mobile universe towards organization, that is, forming relatively immobilized (stable or meta-stable) distinct configurations of matter that endure each in itself and interact as external to each other. All this without presupposing either a conscious beholder or an active agency for whom they are given as such in intuition, or by the action of whom they are brought forth.

Mobility and immobility are always relative, e.g., there are always things that relative to me are immobile like rocks, or things that relative to them I am immobile like the firing of a neuron or the nanosecond long operations of a microprocessor. Yet, all material configurations remain inherently mobile; nothing remains absolutely immobile. In other words, metaphysical self-organization is only a tendency towards organization which does not result in any specific final order. All actual organizations pass.

A plurality of durations

When things spontaneously separate and do not fully permeate each other, the duration that initially unified them diverges into a plurality of durations. Things coexist and interact in their actual present, but for each this present passes into a duration unique to it and (more or less) inaccessible to all others. As things actually interact their unique duration registers the actuality of their interactions with all other things, and thus things become not only distinct in actuality but also in their enduring past (i.e., in their virtuality). They still reflect each other but now only to the limited extent allowed by their actual interactions. The lines that separate things are always in flux. Within such lines everything endures while across lines things can only interact in their actual simultaneity.

Degrees of endurance and separation

In this very sense things can be said to have a past – duration – a virtuality that to a larger or lesser extent affects and is being affected by their present – their actuality. The extent to which a specific thing endures depends on the degree to which its past is contractible and dynamically interacts with its actuality. For example, one's personal memory affects one's actuality and is continuously affected by it. Yet, there are additional layers of memory: one's genetic memory, which reflects the human species and the whole of evolved life and yet deeper, there is the molecular/atomic memory encoded in one's chemical structure, which reflects the physical universe as a whole (we are made of star dust...). The genetic memory, however, is to a large extent immobilized in one's lifetime and the memory encoded in the body's atomic/molecular structure is even more immobilized. While one's personal memory is fully contractible and endures with one's actuality, the genetic and molecular memories only affect our actuality, but are hardly affected by it[12]. Consequently, the duration of the human species, or the duration of the physical universe are mostly indifferent to the existence of a single human individual. Human individual existence does not endure (or does so in most cases to a negligible degree) either in the life of the species or in the universe at large. Following this line of reasoning, human individuals are like islands of mobility in an ocean of immobilized memory. Even if they share actual experiences, these pass into their unique and isolated durations and will affect their future interactions differently. Only by means of symbolic representation of their experiences can individuals ground mutual experiences and to some extent bridge their isolated durations (see also 3.3.3). Yet, even so, considering the human capacity of intimate interaction, if the minute internal movements of each individual find their actual expression in interaction and affect the other, their durations can nevertheless be said to converge into a single enduring flow.

It follows that as the universal duration diverges, the things that emerge do not entirely endure in each other but are also not entirely distinct and separate. Since things reflect the whole of duration (and therefore each other) but only to various limited degrees, neither unity nor separation can be said to be absolute. Relations between things are both relations of exteriority and interiority to different degrees. Things endure therefore not only for cognitive agents or in a universal duration. They endure also for the limited totality of other things they actually interact with. Beginning with the second hypothesis in 3.4.3 we reach the third.

Universal perception

As things interact they manifest a universal perception mechanism. The perception by a thing of any other thing singles out the specific modes of interaction between them just as was described for the perception of a cognitive agent. Similar to how perception makes extended things more or less distinct for a cognitive agent in a manner that serves its tendencies, so all extended things perceive other such things as more or less distinct according to their own unique enduring tendencies.

Universal perception is virtual. To further understand this point, we follow the application of intuition that was already discussed: "There would still remain this second conclusion, which is of a more metaphysical order - viz.: that in pure perception we are actually placed outside ourselves [and inside the object]; we touch the reality of the object in an immediate intuition." (Bergson, 1991, p. 75). This can be read to mean that in pure perception (without the intervention of memory) the mind of the perceiver extends itself into the things being perceived. Touching the reality of an object from within by placing one's mind in it, is what Bergson calls intellectual sympathy.

[12]Genetic memory is to some extent affected by epigenetic changes that may be triggered by individual experience.

In being perceived, therefore, extended material things partake in a mind, but the mind they partake in is not entirely theirs. The crucial point here is that at the instance of perception, *this mind is not entirely the perceiver's either*; it is shared among all perceived things at that moment. Ultimately, the mind manifesting as intuition at every moment does not strictly belong to any single thing yet it partakes in all things perceived by each other. Intuition is never anyone's intuition about something else. It is rather the absolute knowledge of something and must therefore be internal to that thing. Intuition inasmuch as it is accessible forms a relation of interiority. In other words, intellectual sympathy cannot be considered to be a simple property or a capacity possessed by this or that cognitively able agent or some other embodied entity with a brain. It is rather a *relation of interiority formed among things*. The term intellectual sympathy is somewhat confusing because it erroneously invites one to think about things as having an intellect. This is far from being the general case. In metaphysical terms, things are never entirely separated. The totality of ways in which they can affect and be affected by each other is virtually accessible to them as a kind of rudimentary intuition they share but is only realized as an actual interaction. In universal perception we mean exactly this: the mutual progressive determination of actual interactions starting from the intuition of things virtually accessible to each other, and culminating in actual interactions (compare to 3.2.2).

Stable objects, states and relations arise because their actual interactions become spontaneously limited, that is, their repertoire of activities becomes mutually constrained. In terms of Bergson's cognitive theory they gain a more or less rudimentary perception of each other; as explained, they perceive each other only to the limited extent they can possibly affect each other (see discussion 3.2.2). Once such rudimentary perception arises, a rudimentary duration is there too as actual interactions pass into it. This duration is none other than a span of undifferentiated tendencies that participate in the determination of a future actual interaction. The perception an extended thing has is synonymous with its mobile and immobile relations with all other things.

Cognitively able embodied agents

Complex configurations such as living systems or human agents are only special cases in a continuum. Inasmuch as symbolic representation is available to such systems, it serves in both immobilizing the flow of actual activities and forming concrete memories out of a mobile duration. Cognitive agents endowed with such linguistic and concept forming capabilities as means of immobilization are therefore powerful catalysts of self-organization in that they bring forth a world of objects, states and relations. The image of thought discussed in chapter 2 encompasses all immobilizing activities and is but a tiny aspect of the vast expanse of self-organizing activity described here, which rarely crosses the threshold of producing symbolic representations.

Beyond realism and idealism

Metaphysical self-organization is not to be confused with realism per se, which presupposes observer-independent existence. Instead, this hypothesis follows Bergson's line of thought to its logical extreme: under the condition of mobility and heterogeneity, everything observes and is being observed, everything perceives and is being perceived and consequently everything endures in everything else (to various degrees). Metaphysical self-organization is also far from proposing that everything endures only as an immobile idea accessible only to a limited set of presupposed cognitively able agents. Ideas are always secondary products of a fundamental mobility. In this sense, metaphysical self-organization as discussed here must be taken for what it is: a mobile reality boxed into an immobilized figurative representation, just keeping in mind that there is much more to it than what can be possibly expressed in words.

Summary

Metaphysical self-organization is the hypothesis that the metaphysical continuum conceived by Bergson spontaneously manifests objects, states and relations with various degrees of relative mobility and immobility. It is a tendency engendering a productive process that brings forth a world of interacting things, states and relations. The resulting field of interaction forms a third kind of multiplicity (see 3.3.1, 3.3.2) which is both discrete and qualitative.

All things, whether conscious or not, partake in a distributed mind (in the sense explained above) which is neither entirely unified nor entirely plural, neither universal nor localized. This is virtual co-existence.

The event of cognition and metaphysical self-organization are complementary descriptions. While the first term highlights a metaphysical meeting point (virtual-actual, mobile-immobile), the second term highlights its fundamental mobility and flow ("a living and therefore still moving eternity").

Such is the fundamental complexity of reality underlied by this metaphysics of change and self-organization.

Chapter 4

Deleuze's Nomad Reality

With a palpable notion of the virtual presented in chapter 3, the ground is ready to move on to Deleuze's work on the nature of reality. Rooted in Bergsonian metaphysics, Deleuze develops a formidable metaphysical structure of his own, revolutionary in its implications and profound in its reach and span. Three primary aspects characterize Deleuze's project: *a*) mobility and difference rather than stable identities as the fundamental metaphysical ground (e.g., (Deleuze, 1994, p. 41)), *b*) the problem of thought beyond the human condition (Pearson, 1999, chap. 1), and *c*) thinking, philosophical thinking (primarily metaphysics) as a process of creation rather than discovery of what already exists (May, 2005, p. 16). The first aspect is definitely shared with Bergson in claiming that reality is fundamentally mobile, or in Deleuze's terminology, nomadic rather than sedentary (i.e., movement rather than localities as fundamental). In order to realize this aspect Deleuze recreates two foundational concepts that are conventionally based on identity: difference and repetition. He makes difference rather than identity a metaphysical element and shows how all repetitions are repetitions of differences.

The second aspect is perhaps Deleuze's most radical innovation compared to Bergson. In developing his metaphysical system, Bergson's point of departure is human cognitive processes, human consciousness, and human intuition. These leave their undeniable signature on his metaphysical system. Even when he goes beyond what is given to human consciousness in intuition, the conscious subject (or rather its absence) seems still to have left a trace that raises many problems (Deleuze, 1991, chap. 4). As we will see shortly, Deleuze's metaphysics is much cleaner and elegant in its construction. His method neither assumes a specific manner of thinking as it is known to human subjects (the image of thought), nor presupposes a thinking agent. The third aspect involves many theoretic innovations significant in the context of the history of philosophy and the evolution of philosophical thought and its methods[1].

Together, the three aspects provide an entirely novel approach to the problem of the origin of thought – thought as an ongoing process of creation that need not presuppose anything other than its own mobility. We may therefore rephrase our initial problem: it is not about the origin of thought but properly about *thought as origin* – "that by which the given is given."

[1] See for example a brief discussion on Deleuze's transcendental empiricism in chapter 10.

The outline of Deleuze's metaphysical system is similar to Bergson's: while conventionally the real is identified with the actual, for Deleuze, reality as such is mobile and two faceted; having actual and virtual dimensions (Williams, 2003, pp. 7-11):

> "The virtual is opposed not to the real but to the actual. The virtual is fully real in so far as it is virtual. Exactly what Proust said of states of resonance must be said of the virtual: 'Real without being actual, ideal without being abstract'; and symbolic without being fictional. Indeed, the virtual must be defined as strictly a part of the real object - as though the object had one part of itself in the virtual into which it plunged as though into an objective dimension." (Deleuze, 1994, pp. 209-210)

From the outset (and in contrast to Bergson for whom it was rather a later development), the virtual dimension is as real as the actual dimension:

> "The reality of the virtual consists of the differential elements and relations along with the singular points which correspond to them. The reality of the virtual is structure. We must avoid giving the elements and relations which form a structure an actuality which they do not have, and withdrawing from them a reality which they have." (ibid., p. 210)

Where Bergson's virtual duration is only vaguely structured in the form of a cone (see: 3.3.2), Deleuze gives the virtual dimension a quite detailed structure, but unlike any kind of actual structure. The structure of the virtual is all about change: differences, variations and relations of variations. It is the virtual dimension that bears upon what actually happens moment by moment, but otherwise it is causally sterile. It is not the virtual aspect of an object that causes actual change, but rather actual change that selectively expresses (individuates) virtual tendencies. The actual dimension of reality is a universe of interconnected and interacting individuals affecting and being affected by each other. That reality is both actual and virtual means that difference and change are inherent in every aspect of it. Identity and stability may often be actual features of objects and states of affairs but this actuality is only a surface – an appearance. Underneath, however, actuality hides a virtual depth pregnant with tendencies and tensions that may surge to the surface of actuality at any moment[2]. The real is always in flux, always different from itself. Hence a nomad reality.

The virtual and the actual dimensions do not constitute a dualism; they incessantly penetrate, reconfigure and reflect each other. This intimate relation, already made palpable to some extent in the previous chapter, is the fundamental reality according to Deleuze. This chapter is dedicated to exploring the structural aspects of both the virtual and actual dimensions whereas the next will discuss the virtual-actual dynamism. In both, many of the concepts presented in chapter 3 are thoroughly reworked and extended. Here we witness an evolution of a philosophical

[2]Notice that the sense the description here delivers draws on the concepts of exteriority (formed surface) and interiority (unformed depth) already developed in chapter 3.

system where the older Bergsonian one is radically transformed yet endures in the novel Deleuzian one. This is a fine demonstration of how the Deleuzian philosophical method is put to work.

4.1 Difference and Repetition

4.1.1 The Concept of Difference

Difference is a foundational element in Deleuze's metaphysics and the articulation of the structure of the virtual. Deleuze's concept of difference – difference in itself, is difficult because it radically departs from the various conventional ways difference is understood. For example, while difference is considered as something that separates between things, or negates something, at least in some aspects, Deleuze's concept of difference in itself is to be understood in terms of radically connecting and affirming. Why, how and to what end? Limitations of space will not allow here a thorough review of the careful construction of the concept in (ibid., chap. 1) (see also: (DeLanda, 2013; Williams, 2003)). Only the most significant characteristics are elaborated here, providing nothing more than a useful caricature that leaves behind a trove of philosophical insights.

What does difference in itself mean? Conventionally, when thinking about difference, we think of difference from something that is already defined and known, or a difference between things that already have something in common and are thus further differentiated and made distinct. Things that share nothing in common can hardly be said to differ in any sense. They are just incomparable. Using the terminology already discussed in chapter 3, difference is a relation of exteriority between things that are laid out as partly or wholly distinct (but sharing some space where they are made comparable). More formally, the very notion of difference is bi-lateral: if A is different from B in some sense X, necessarily B is different from A in the same sense. E.g., if X is colour, and A differs from B in its colour, necessarily B is different from A in colour too. In contrast, difference in itself is not a relation of exteriority and does not presuppose anything it needs to relate. The 'in itself' of difference according to Deleuze is a relation of interiority. Recall from the previous chapter the construction of the concept of duration where all of the past endures in each present moment and when the present passes it changes all of the past. By analogy, a relation of interior difference is exactly this: when something changes yet endures in the change and is inseparable from it. Bergson observed it in the movement of states of consciousness, Deleuze gave it a definition of almost mathematical precision:

> "Difference is the state in which one can speak of determination as such. The difference 'between' two things is only empirical, and the corresponding determinations are only extrinsic. However, instead of something distinguished from something else, imagine something which distinguishes itself - and yet that from which it distinguishes itself does

> not distinguish itself from it. Lightning, for example, distinguishes itself from the black sky but must also trail it behind, as though it were distinguishing itself from that which does not distinguish itself from it. It is as if the ground rose to the surface, without ceasing to be ground. There is cruelty, even monstrosity, on both sides of this struggle against an elusive adversary, in which the distinguished opposes something which cannot distinguish itself from it but continues to espouse that which divorces it. Difference is this state in which determination takes the form of unilateral distinction." (Deleuze, 1994, p. 28)

Deleuze uses the word cruelty to lend a sensation to an ultimately abstract event. Difference as a unilateral determination is a point of apparent struggle, crisis and collision of wills[3]: the will to remain indistinct and the will to differ and by that create. These wills, however, are interior to each other and inseparable. Critically, the part that cannot distinguish itself from the other part (and continues to espouse that which divorces it...), must be indistinguishable in itself and not only in relation to the recent determination. It must not contain distinct separable parts. If this were not the case, the unilateral relation thus described would make no sense.

The part that is indistinguishable, therefore, endures as such without ever becoming separate in itself or separate from that which 'divorces' it. If we further inquire as to the minimal conditions that make possible such unilateral determination, we must assume some kind of *a priori* inherent mobility and in this case it follows that the 'espousing' part contains already innumerable unilateral distinctions or differences in itself. The reasoning behind this point is simple: if there is even one unilateral determination, it means that determination is possible. But if it is possible, it was always possible because if it was not, either we could not speak of difference in itself at all, or, we would have to assume an unfathomable cause that suddenly made the impossible possible, but that cause should have been somehow determined just before that, which does not make sense. So determination being always possible means that once we imagine difference in itself we must imagine all such differences as coexisting at once. Difference in itself, therefore, is inherently multiple where each difference implies a multiplicity of differences, each of which in turn implies another multiplicity ad infinitum. Since each difference is a unique determination (incomparable to any other), all multiplicities are also heterogeneous.

Difference in itself seems almost magical in a sense analogous to certain very simple mathematical formulas that generate immensely complex fractal structures. Though it is given in terms of a single event of unilateral determination, difference in itself is an infinitely generative element that intrinsically enfolds infinite variety. In contrast to any mathematical formula, however, there is no limit to the variety difference in itself enfolds (this is what Deleuze might have referred to as monstrosity). The implied generated structure has neither a point of origin nor endpoints. It

[3]Later termed intensities see 4.2.1.

is anisotropic in the sense that every point is a source to infinite unique and incomparable differences. Points therefore cannot be distinguished or gain a privileged status by features of their neighbourhood, no matter how large the neighbourhood is made. For all such neighbourhoods the point is only the 'espousing' indifferent.

What we have at hand is a description of a vast plane of pure differences without anything concrete to be different from. Though it carries some resemblance to Bergson's virtual duration and shares with it some fundamental features, it is barer and vaster. Barer because while Bergson's virtual dimension is a qualitative continuum (that becomes extensive in the extreme), difference in itself is neither qualitative nor extensive. Vaster because Bergson's duration populates only what has already happened (the past) while difference in itself involves also determinations that never reached actualization.

The bare logic of difference in itself is to do with determination and only with determination. The indeterminate is completely indifferent, but in as far as it is determinable, we can speak of unilateral determination – a difference in itself and what follows as described above. Interestingly, Deleuze finds this bare determination to be the element of thought: "[...] since thought is that moment in which determination makes itself one, by virtue of maintaining a unilateral and precise relation to the indeterminate. Thought 'makes' difference, but difference is monstrous." (ibid., p. 29) It is here that Deleuze hints about thought beyond the human condition. Still, in its nakedness thought lacks any form, image or direction.

The significance of difference in itself can be appreciated only in the wider perspective of the history of philosophy. Deleuze argues that difference never had a concept and was only meaningful in terms of other concepts and their relations in a system of representation that relates already formed and well defined entities:

> "As a concept of reflection, difference testifies to its full submission to all the requirements of representation, [...] In the concept of reflection, mediating and mediated difference is in effect fully subject to the identity of the concept, the opposition of predicates, the analogy of judgement and the resemblance of perception. Here we rediscover the necessarily quadripartite character of representation. The question is to know whether, under all these reflexive aspects, difference does not lose both its own concept and its own reality." (ibid., pp. 34-35)

In effect Deleuze aims to construct a metaphysics of difference where difference in itself rather than identity is the foundational element. This is a high stakes challenge considering that it aims to undo philosophical systems meticulously developed for thousands of years. At the crux of the challenge is understanding being:

> "All things cannot be in the same way since things are different. It is different to be a rock and an animal - they are in different ways. Therefore, to be is to be what you are and not simply to be. Being is equivocal [...]" (Williams, 2003, p. 63)

An equivocal being is exactly the being of what something is – a well defined entity, and nothing else. The sense of being a rock is incomparable to the sense of being a person, in other words, things are inherently separate and distinct in the sense they exist. But an existence that arises from generative difference in itself is entirely connected and things in as far as they exist must exist in the same sense because after all they differ only in certain determinations (on how concrete things arise in the following). To counter an identity-based metaphysics, Deleuze must therefore counter equivocal being with univocal being – that all things exist in the same sense: "There has only been one ontological proposition: Being is univocal." (Deleuze, 1994, p. 35) And he clarifies:

> "In effect, the essential in univocity is not that Being is said in a single and same sense, but that it is said, in a single and same sense, of all its individuating differences or intrinsic modalities. Being is the same for all these modalities, but these modalities are not the same. It is 'equal' for all, but they themselves are not equal. It is said of all in a single sense, but they themselves do not have the same sense. The essence of univocal being is to include individuating differences, while these differences do not have the same essence and do not change the essence of being [...] Being is said in a single and same sense of everything of which it is said, but that of which it is said differs: it is said of difference itself. " (ibid., p. 37)

Importantly, while being includes individuating differences, it does not provide an overarching unifying principle to all those differences as if they are related or applied to some primordial oneness that they divide. Univocal being therefore stands at the root of multiplicity. The individuating differences Deleuze mentions here are those unilateral determinations that eventually bring forth concrete forms out of the indifferent (though we still do not know at this stage how). With this move of shifting from equivocal to univocal understanding of being, Deleuze effectively replaces identity with difference as a primary metaphysical element and subordinates everything to difference:

> "That identity not be first, that it exist as a principle but as a second principle, as a principle *become*; that it revolve around the Different: such would be the nature of a Copernican revolution which opens up the possibility of difference having its own concept, rather than being maintained under the domination of a concept in general already understood as identical." (ibid., pp. 40-41)

In the following he outlines broadly a metaphysical structure realizing the above:

> "We must show not only how individuating difference differs in kind from specific difference, but primarily and above all how individuation

> properly precedes matter and form, species and parts, and every other element of the constituted individual. Univocity of being, in so far as it is immediately related to difference, demands that we show how individuating difference precedes generic, specific and even individual differences within being; how a prior field of individuation within being conditions at once the determination of species of forms, the determination of parts and their individual variations. If individuation does not take place either by form or by matter, neither qualitatively nor extensionally, this is not only because it differs in kind but because it is already presupposed by the forms, matters and extensive parts." (ibid., p. 38)

Central to this scheme is the concept of *individuation*: difference in itself as a field of individuation is virtual, it is not active, it is not a difference from anything actual (as actual differences are), neither it is a difference for someone actual (differences within representation). It exists as an element of pure change and its relations to the actual are yet to be clarified. To foreshadow the topic of chapter 5, the field of individuation is quite like a vast territory (the ground in Deleuze's terminology) which is also a map. It is a map in the sense that lines (trajectories) of consecutive determinations can be drawn across it that bring forth actual individuals (see (Deleuze and Guattari, 1987, pp. 12-21)).

Though we now have a clearer grasp of Deleuze's plan and the primacy it assigns to difference, we are still far from understanding at this point how unilateral determinations bring forth a world of actual (and representable) objects and relations. Yet Deleuze is guiding our sight always to see difference in itself and the connectivity underlying the apparent even when actually we experience borders, limits, separation and negation in a realm of representations:

> "There is a crucial experience of difference and a corresponding experiment: every time we find ourselves confronted or bound by a limitation or an opposition, we should ask what such a situation presupposes. It presupposes a swarm of differences, a pluralism of free, wild or untamed differences; a properly differential and original space and time; all of which persist alongside the simplifications of limitation and opposition. A more profound real element must be defined in order for oppositions of forces or limitations of forms to be drawn, one which is determined as an abstract and potential multiplicity. Oppositions are roughly cut from a delicate milieu of overlapping perspectives, of communicating distances, divergences and disparities, of heterogeneous potentials and intensities." (Deleuze, 1994, p. 50)

Here Deleuze posits a profound real element – a heterogeneous multiplicity of differences (synonymous to the field of individuation mentioned above) from which oppositions of forces and limitations of forms are drawn. It again infers a virtual dimension complementary to the actual that precedes it in the sense that production precedes the product (we will see later in 4.2 that production not only creates but destroys as well).

4.1.2 Repetition... Repetition...

In 4.1.1 we learn how Deleuze frees difference from its subordination to identity and establish it as a metaphysical element. Here we follow how the concept of repetition is treated towards the same end: defining it independently of identity. Together, difference and repetition are the building blocks of Deleuze's metaphysics.

Passive Synthesis – Repetition for itself

"Repetition is not generality" is the first sentence of Deleuze's *Difference and Repetition*. Conventionally, the concept of generality derives from resemblance between things. Establishing resemblance between terms or instances, i.e., distinguishing the properties they share, is equivalent to defining the identity from which they all derive. Generality therefore is a concept based on identity and where differences are secondary and less significant. Repetition as generality means the reappearance of the same but with some insignificant differences. Resemblance allows things to be seamlessly substituted or replaced by each other at least in a certain significant sense. For example, when repeating a scientific experiment in order to confirm a theory, the said experiments are of course different in many aspects but they confirm each other because in general they are believed to be conducted in the same manner. Deleuze in contrast develops repetition from an entirely different premise:

> "[...]we can see that repetition is a necessary and justified conduct only in relation to that which cannot be replaced. Repetition as a conduct and as a point of view concerns non-exchangeable and non-substitutable singularities. Reflections, echoes, doubles and souls do not belong to the domain of resemblance or equivalence; and it is no more possible to exchange one's soul than it is to substitute real twins for one another. [...] To repeat is to behave in a certain manner, but in relation to something unique or singular which has no equal or equivalent. And perhaps this repetition at the level of external conduct echoes, for its own part, a more secret vibration which animates it, a more profound, internal repetition within the singular." (Deleuze, 1994, p. 1)

Repeating is always in relation to something unique, singular and irreplaceable[4]. In opposition to conventional thinking where what makes repetition matter is resemblance between the instances of repetition (that which is deemed repeating), Deleuze

[4]Already at this very early stage in his book Deleuze hints that actual repetition only reflects another, unseen or 'secret' repetition internal to the singular being repeated. This is the repetition of the virtual Idea as explained in 4.2.3 ahead.

focuses on the difference among the instances. For there to be repetition, instances of the repetition must differ from each other (e.g., in place, in time, or other details). Repetition therefore cannot be rooted in the identity of the terms. It is differences synthesized together and not the points of similarity that makes repetition matter (Williams, 2003, chap. 2). In other words, what repeats are differences, but the question remains, repetition for whom or for what?

The condition of repetition cannot be found in the repeating instances, as these cannot be implied to have any *a priori* relation between them. Repetition does not and cannot take place within the instances, but must be carried out externally to them, meaning that any repetition must be repetition *for* something (or someone) other than its instances. In other words, repetition must have a space or a background where it takes place. For the very same reasons mentioned in chapter 3 regarding multiplicities, there must be a space where an instance of repetition appears and where other instances did not disappear but endured. There must be a notion of accumulation where instances are composed or synthesized into a repeating series:

> "A succession of instants does not constitute time any more than it causes it to disappear; it indicates only its constantly aborted moment of birth. Time is constituted only in the originary synthesis which operates on the repetition of instants. This synthesis contracts the successive independent instants into one another, thereby constituting the lived, or living, present. It is in this present that time is deployed. To it belong both the past and the future: the past in so far as the preceding instants are retained in the contraction; the future because its expectation is anticipated in this same contraction. [. . .] In any case, this synthesis must be given a name: passive synthesis. Although it is constitutive it is not, for all that, active. " (Deleuze, 1994, pp. 71-72)

The concept of passive synthesis is critical to Deleuze's understanding of repetition. It is a constitution of instances, singular and unique, into another instance that contains them. Within this new instance the composed instances hold a relation of interiority. It is only on account of their endurance within each other that repetition is said to be. To gain a further intuition of the idea, repetition is a synthesis in a manner similar to how movement is a synthesis of consecutive locations in space (see 3.3.2). Bergson argues that there is something more to movement than just a sequence of positions in space because in movement the positions endure. By analogy, there is more to repetition than just the sequence of instances because in repetition the instances are passively synthesized and brought into an enduring continuum. It is this continuum that makes repetition matter. The synthesis is passive because it does not require an external intention or action to take place. It is passive in the sense that it is not for anyone in particular; it is only for itself and *it is its own background* ("It is not carried out by the mind, but occurs in the mind which contemplates, prior to all memory and all reflection."). Were it for something or somebody else it would already be an active synthesis – something or somebody intentionally composing it in mind or imagination. As such the passive synthesis constitutes time itself (Deleuze, 1994, chap. 2).

For example, a step is a sequence of movements of the body and especially the legs. The right leg moves forward, and then the left leg moves etc. The sequence can be much more detailed of course: lifting the right leg, moving this or that muscle and so on. These movements are passively synthesized into a single instance called step. Walking is a repetition of steps, each of which is unique in relation to both the body and the ground since the irregularities of the ground will require corresponding unique adjustments of the body in performing the movements composing each step. Conventionally, walking is a repetition because its terms, the steps, are identical in concept and differ only in minor insignificant details. Consequently, steps are interchangeable with each other and because of their generality repetition matters. According to Deleuze this consideration is erroneous because in reality there is no such thing as a 'general step'; it is a fiction, an illusory invention. All steps are unique individuals and repetition is a synthesis of such individuals. The second, the third, and the following steps repeat the first because each adds a difference to steps already made and endured, that is, the second step is a repetition only because the first did not disappear once the second appeared and neither of them disappeared once the third appeared etc. Notice also that when the third is enacted the first two are not actual. They belong to the virtual and only endure in the actual step. It is only the contraction (passive synthesis) of successive individual steps that is actual repetition. Furthermore, not only does every new step change the repetition already made, it is also unique because the ground being walked upon is changing. What repeats in walking are unique body-ground adjustments i.e., a contraction of instances of difference (see 4.2.1 ahead).

Enclosed within each step, there is another repetition of a sequence of body movements (right up and forward, left up and forward etc.) where each movement is anticipated by the previous one and anticipates the one that follows. In relation to a single step, these movements are no longer distinct. They are passively synthesized into an inseparable continuum with a beginning and an end which is where a step begins and ends. Inasmuch as steps are repeating, this sequence is a repetition, no less: Left leg movement *is always* followed by right leg movement, right always followed by left. It is a relation that repeats. As steps are unique so are the movements within each step: they keep a relative ordinal order but are also variable e.g., the right leg lifts a bit higher and then the left extends a bit further etc. This is a repetition within a repetition: the first external repetition of steps in walking is open-ended since an indefinite number of steps can accumulate into a 'walk'. In contrast, the second internal repetition is enclosed and finite. The first repetition relies on the second, but it is also correct to say that only in relation to the first (repetition of steps), the second repetition becomes enclosed.

An objection can be raised here that the pattern of left leg always following the right leg is the element of identity that makes all steps *a priori* similar. To answer this important objection requires the full extent of the metaphysical system. At this stage we can only sketch the argument: it is not that the identical element within all steps precedes the repetition but it is the other way around. The identical element appearing in all individual steps is only an effect of repetition and presupposes it. An actual step has a corresponding virtual step which is a multiplicity that already contains all possible variations contracted together but indistinctly (like the internal multiplicity of moments contracted in duration). Whenever an actual step is made, it is a unique individual expression drawing from this internal multiplicity. As we will see in 4.2.3, actual steps are all expressions of a 'virtual Idea' which is a multiplicity entirely constructed from differences. This is exactly what Deleuze meant by: "...this repetition at the level of external conduct echoes, for its own part, a more secret vibration which animates it, a more profound, internal repetition within the singular." Every actual individual step expresses a passive synthesis of virtual differences it hides beneath its appearance.

An actual individual step is not a derivation from a generality. It is a relation between two repetitions or two contractions. In this case, walking is the *enveloping* repetition because it contracts many instances of stepping and the specific pattern of body movements is the *enveloped* repetition contracted into every step. These two orders of repetition co-define each other and in that bring forth steps between them. Every step is a unique individual instance but stepping is also a habit. The identity implied in every habit is an effect of repetition, and not the reason presupposed by it. This effect is achieved by averaging all the different terms of repetition to bring forth a representative step within a system of representation where all differences are eliminated.

Systems of Signs

The world is a rich structure of repetitions, open-ended or enclosed within each other. We can continue the example to further examine the concept of dance. A specific dance is again a passive synthesis enclosing a finite number of unique steps into a single instance, say 'Tango'. Dancing Tango means therefore repeating a sequence of sequence of steps. When a dancer is masterful he/she will even introduce deliberate variations at multiple levels that make the dancing more lively and less mechanical.

Dance, walk and step brought forth by orders (or levels) of repetition are cases of what Deleuze calls *signs*. A step is a sign, Tango is a sign that is composed of other signs etc. Signs are products of passive syntheses and as we learned, every instance of a sign is a unique individual. There is no *a priori* principle of resemblance to make the instances of a sign comparable. In other words, comparability is the effect of repetition and not its condition. Signs at any level participate in other syntheses, passive or active, and form complex hierarchical and recursive structures. Such structures compose actual reality:

> "We must therefore distinguish not only the forms of repetition in relation to passive synthesis but also the levels of passive synthesis and the combinations of these levels with one another and with active syntheses. All of this forms a rich domain of signs which always envelop heterogeneous elements and animate behavior. Each contraction, each passive synthesis, constitutes a sign which is interpreted or deployed in active syntheses. The signs by which an animal 'senses' the presence of water do not resemble the elements which its thirsty organism lacks. The manner in which sensation and perception - along with need and heredity, learning and instinct, intelligence and memory - participate in repetition is measured in each case by the combination of forms of repetition, by the levels on which these combinations take place, by the relationships operating between these levels and by the interference of active syntheses with passive syntheses." (Deleuze, 1994, p. 73)

Here Deleuze outlines a formula of how reality is constituted in the repetition of individual instances and how apparently stable behaviours (or even objects and their boundaries) are in fact relations among repeating patterns of change. On the basis of passive syntheses Deleuze explains the concept of habit that underlies just about everything said to have a persistent existence. Most importantly, recognition in representation is in fact a repetition. It is not hard to see how repetition and the contraction of instances allude to the mechanism behind metaphysical self-organization, as presented at the conclusion of chapter 3, but to get the full picture quite a few additional details need to be elaborated.

Repetition and Difference

The discussion to this point shows how actual cases of repetition are based on the synthesis of different instances that do not derive from a prior identity. The next step is understanding that actual repetition always hides an internal virtual one:

> "Necessarily, since this repetition [virtual repetition] is not hidden by something else but forms itself by disguising itself [in actual expressions]; it does not preexist its own disguises and, in forming itself, constitutes the bare repetition [the actual external one] within which it becomes enveloped. [...] It is true that we have strictly defined repetition as difference without concept [i.e., not derived from identity]. However, we would be wrong to reduce it to a difference which falls back into exteriority, because the concept embodies the form of the Same, without seeing that it can be internal to the Idea [see 4.2.3] and possess in itself

> all the resources of signs, symbols and alterity which go beyond the concept as such. [...] We therefore suggest that this other repetition [the virtual one] is in no way approximative or metaphorical. It is, on the contrary, the spirit of every [actual] repetition. It is the very letter of every repetition, its watermark or: constitutive cipher. It forms the essence of that in which every repetition consists: difference without a concept, non-mediated difference. It is both the literal and spiritual primary sense of repetition. The material sense results from this other, as if secreted by it like a shell. " (ibid., pp. 24-25)

The first point of this important quote is that every actual repetition hides a virtual repetition which is the essence of repetition. What is this virtual repetition? We have already showed that difference in itself is intrinsically multiple without ever being one or many[5]. We can say therefore that difference, in as far as it is different in itself, repeats. It repeats not for something outside itself (in the sense of a separate entity) but for itself in itself. The same notion of a passive synthesis can be applied to further clarify this inner repetition. Differences as unilateral determinations are synthesized together to form compound differences. Any difference can be composed from an ordinal series of other differences while preserving the unilateral property all along. Every consecutive term in such series is a difference determining something not yet determined in the previous term and as the sequence proceeds, each term endures in the following one. What passive synthesis in this repetition means is that any number of such consecutive terms in a series of differences can together compose a compound difference – a single determination that includes all at once the determinations of the terms involved[6]. Clearly, the compound difference remains a unilateral determination but now a more complex one.

Deleuze notes that certain compound differences are expressed in signs that are the instances of actual repetitions as discussed before. But how do the developing series of differences contract into the virtual differences corresponding to signs? There are additional structural elements of the virtual that explain why certain sequences of difference synthesize together while other sequences do not. This has to do with distinctive points or singularities, further discussed in 4.2.3.3. In a nutshell, as differences develop, the development has turning points, e.g., something grows for a while and then diminishes. The point in the development where a positive change turns into a negative one is distinctive. It can be said that series of differences are punctuated by singular points. The manner of how such series are segmented into enveloping differences is based on these singularities that delineate the segments. This is of course a simplified description. Much more complex syntheses are intrinsic to the virtual structure and these correspond to the complex systems of signs that

[5]The one and many are concepts which define each other and presuppose distinctiveness and homogeneity. In the case of virtual differences, since the multiplicity is interior to difference, there are no distinct terms that can be related as one or many.

[6]Notice that the determinations are in principle heterogeneous and their composition is nothing like quantitative addition.

constitute actual reality. Up to this point, the description given to virtual differences could infer only an interconnected yet infinitely heterogeneous disordered virtual plane. Repetition and orders of repetition, as expressions of virtual singularities, enable the emergence of signs and the complex structures they constitute.

It is easy to underestimate the richness and complexity allowed by difference and repetition. There is no end to the depth of possible compositions as each term in every series can itself be a synthesis and hide another internal series along with its distribution of singularities. In other words, there is no ground level of metaphysical 'atomic' differences; it is differences all the way down[7]... As already clarified in 4.1.1, differences can only be said to differentiate from an indifferent ground. Series of differences have no identifiable absolute origin (or end point) from which they unfold. If this were the case, differences would fall back to be subjected to an original identity. Furthermore, differences cannot be situated precisely in relation to other differences, that is, to be quantified in terms of such other differences, because this would mean that though the series has no origin there is a 'seed set' of differences that can be deployed as a compound origin from which all other differences can be derived (Williams, 2003, p. 27). Virtual repetitions and their corresponding expressions bring forth a world of *simulacra* which is a contrasting alternative to a world based on "superior identity" (Deleuze, 1994, pp. 126-128). In summary, repetition and difference thus redefined provide the corner stones of a nomad reality that does not require any reference to identifiable metaphysical elements. In the following we attend to how the structure of such reality is further specified.

4.2 The Structure of the Virtual

What we aim to achieve in articulating the structure of the virtual is to describe an architecture of change (difference) from which all actual manifestations arise. We have already discussed differences as the primary generative elements of this architecture and series of differences that can be further composed through repetitions into differences of higher order and recursively so.

Series of differences, being series of consecutive determinations, possess a feature that was not highlighted up to this point. Each determination, relative to what was before, is a selective event. It introduces a reduction in the variety of determinations that can follow it. In other words, it breaks the intrinsic symmetry of the indifference that precedes it. If this were not the case, the indifferent would always remain indifferent and every determination would always start from absolute indifference (which is also absolute disorder). A determination must therefore have an effect – to make a difference. Consequently, series of differences are already lines of development or *progressive determinations* that can also be considered as *tendencies*. The specifics of the said development are not given as yet; it is the idea of how series of differences produce development which matters.

[7]Following the old joke on the turtles that support the earth.

DeLanda (2013, chap. 2) gives a detailed articulation of the structure of the virtual in terms of state spaces of dynamic systems. Using such system of metaphors, the above series of differences are described as general trajectories in a vector field describing a dynamic system and where the passive synthesis involved in repetition is achieved by performing the operation of integration along trajectories. Evidently Deleuze was aware of the terminology of dynamic systems and is using such terminology in a few places in his work to derive philosophical connotations e.g., (Deleuze, 1994, pp. 46, 209) and specifically in conjunction to actualization: "In this regard, four terms are synonymous: actualize, differenciate, integrate and solve. For the nature of the virtual is such that, for it, to be actualized is to be differenciated[8]." (ibid., pp. 211) Though it is highly simplified, the state space metaphor[9] can be helpful in navigating the highly abstract terminology of the virtual, as we will see in the following.

4.2.1 Intensities

To gain a full picture of the structure of the virtual, yet another critical element is missing: *intensity*. Here we need first to note an important departure from the meaning of intensity as discussed by Bergson. In chapter 3 intensities were associated with qualitative differences and opposed to quantitative differences. Among other things, the power and elegance of Deleuzian metaphysics is that the virtual aspect of reality is entirely constructed from transcendental elements. Even though such elements are immanent in the actual manifestations that express them, they remain entirely outside the realm of sensible manifestation. For Deleuze both the extensive and qualitative belong to the actual aspect of reality while intensive differences or intensities in short are virtual. The duality in Bergson's philosophy is problematic for a few reasons that will not be discussed here. Bergson had already made the effort to reconcile this duality of the quantitative and qualitative by placing both on a continuum of contractions in duration. Deleuze makes a point of reflecting on this problem and provides an answer not quite similar to Bergson's using differences:

> "The soul of mechanism [divisible extensity] says that everything is difference of degree. The soul of quality replies that there are differences in kind everywhere. However, these are false souls, minor and auxiliary souls. Let us take seriously the famous question: is there a difference in kind, or of degree, between differences of degree and differences in kind? Neither. Difference is a matter of degree only within the extensity in which it is explicated; it is a matter of kind only with regard to the quality which covers it within that extensity. Between the two [i.e., difference in degree and difference in kind in actuality] are all the degrees of difference

[8] This term specific to Deleuzian terminology refer to the synthesis of a difference from a series of differences and is different in meaning from differentiation (with 't'). The closest mathematical term to differenciation is integration along a curve or a trajectory.

[9] Also discussed in more detail in chapter 10.

> - beneath the two [in the virtual dimension beneath what is sensible] lies the entire nature of difference - in other words, the intensive. Differences of degree are only the lowest degree of difference, and differences in kind are the highest form of difference." (Deleuze, 1994, p. 239)

The final sentence leaves an intentional ambiguity as the apparent comparison between differences in degree and differences in kind uses the words 'lowest' and 'highest' but with reference to the non comparable terms, "degree" and "form" respectively. That is to say that though intensity brings forth both extensity and quality, it is not a ground for their unification (or comparison). Intensity is different in itself and does not belong to a system of representation where such questions are addressed and expected to be answered.

For Deleuze, intensity can initially be understood as a term reflecting the dramatization of difference. Every difference implies a certain differentiating force that operates within the indifferent and brings forth a determination – a departure from what is – a becoming. All change (difference) is related to power (intensity). All differences, therefore, are intensities. Inasmuch as difference is a virtual relation, so is intensity. The force implied in intensity is a *power relation* associated with difference. Intensities only interact with other intensities (similar to Nietzschean forces), creating complex configurations. As such, they do not cause actual effects.

Intensity is instrumental to describing relations between series of differences, that is, relations between lines of development or tendencies:

> "Under what other conditions does difference develop this in-itself as a 'differenciator', and gather the different outside of any possible representation? The first characteristic seems to us to be organization in series [this was already discussed in the previous section]. A system must be constituted on the basis of two or more series, each series being defined by the differences between the terms which compose it. If we suppose that the series communicate under the impulse of a force of some kind, then it is apparent that this communication relates differences to other differences, constituting differences between differences within the system. These second-degree differences play the role of the 'differenciator' - in other words, they relate the first-degree differences to one another. This state of affairs is adequately expressed by certain physical concepts: coupling between heterogeneous systems, from which is derived an internal resonance within the system, and from which in turn is derived a forced movement the amplitude of which exceeds that of the basic series themselves. The nature of these elements whose value is determined at once both by their difference in the series to which they belong, and by the difference of their difference from one series to another, can be determined: these are intensities, the peculiarity of intensities being to be

> constituted by a difference which itself refers to other differences [...]" (ibid., p. 118)

Intensities are differences that affect other differences and introduce change within change. The relation between series is bi-directional but need not be symmetrical. In the example of walking over an irregular ground mentioned earlier, the series of differences of the ground's structure affects the series of steps that need to be adjusted (which in turn affects the series of differences composing each step). The steps may in turn have various effects on the ground and over different time scales e.g., steps made on an irregular ground tend to be followed so that trails are formed on the ground in the course of time. Notice, however, that the example is related to intensities that are already actualized intensities whereas the relations of the virtual intensities they express can only be inferred.

The most important philosophical problem in regard to intensities is that they do not introduce resemblance between the coupled series and do not imply by that an identity that needs to be presupposed in order for two series to be coupled: "When we speak of communication between heterogeneous systems, of coupling and resonance, does this not imply a minimum of resemblance between the series, and an identity in the agent which brings about the communication?"(ibid., p. 119) The argument that Deleuze gives can be summarized (and simplified) as follows: the communication or correlation between the two series is already an effect because the series of second order differences is the one from which the other two originate and is 'hidden' beneath them:

> "In other words, these [the correlated series] express only the manner in which it [the correlating series] conceals itself under its own effects, because of the way it perpetually displaces itself within itself [i.e., the unilateral determinations of the connecting series] and perpetually disguises itself in the series. We cannot, therefore, suppose that the identity of a third party and the resemblance of the parties in question are a condition of the being and thought of difference. " (ibid., p. 119)

To clarify the argument further, refer again to the example of walking on irregular ground. A series of irregularities of the ground seems to cause a series of adjustments in the steps. This example can be somewhat confusing because it considers actual series within a system of representation (i.e., there is ground, there are steps of a walking body etc.). In series of pure differences, there are no causal relations, only relations of difference to difference. Nothing causes anything and nothing is being caused. The virtual aspect of walking on the ground does not specify causes only relations. As we will see apparent causes are only secondary effects. The whole dynamics can be described in terms of relations of pure differences that are expressed by how the walking body and ground body affect and are being affected by each other. The resemblance and implied identity that can be derived in actuality all originate from a series of differences that precedes them.

The significance of intensities is double. First, they provide a powerful organizing element by which complex systems of differential relations can be described. Second, intensities are the mediating elements between the virtual and actual dimensions, in that they can be said to be expressed by actual forces that bring forth extensive and qualitative changes; inasmuch as differences are expressed by form, intensity is expressed by force (on this see chapter 5). Actual intensities are driving actual processes of change and tend to cancel in the process. For example, temperature or pressure differences tend to equalize (average) as energy is redistributed in extensity (e.g., in weather systems). The tendency to equalize, however, is confined only to the actual dimension (see also 5.2.2).

4.2.2 Multiplicities

Bergson identified two kinds of multiplicity; a quantitative multiplicity and a qualitative one that was used to describe duration. Multiplicity, or *variety* as Deleuze sometimes refers to it, is central to Deleuze's metaphysics and shares quite a few features with Bergson's second kind of multiplicity. The major difference between the two terms is that Deleuze's multiplicity is not qualitative. It is not felt or experienced but is purely differential. As discussed earlier, difference in itself implies a multiplicity. The ground, from which all differential determinations arise, endures in all of them and relations within the multiplicity are relations of interiority. A note in (Deleuze, 1994, p. 331) argues that Bergson's duration "is indistinguishable from the nature of difference, and as such includes all degrees of difference: hence the reintroduction of intensities within duration..." Nevertheless, Deleuze's description of multiplicity seems to present a significant difference in relation to Bergson's at least in its structural simplicity.

Multiplicity is the least constrained structure of the virtual. Through repetition differences develop into series of differences, each of such series is a multiplicity. Moreover, every single difference can also have an indefinitely fine structure of differences in itself. This gives rise to an indefinitely complex and interconnected architecture – a multiplicity of multiplicities. Multiplicities are fully interconnected and because of their interconnectedness, no part of the virtual is excluded or separated from any other part. In this sense the virtual as a vast multiplicity is a pure interiority; it has no exteriority but the actual. Consequently, the virtual does not give rise to relations of negation or opposition – it is purely affirmative. Intensities are conducted (figuratively speaking) from any point to any other point within multiplicity, which means that everything can affect and be affected by everything else though only along certain lines of development that are determined by the relations among such lines (see ahead 4.2.3). Such relations indeed reflect certain constraints that are implied in the virtual structure, in developing tendencies and in systemic relations (intensities) prior to any specific actualization.

In terms of actualization it means that if one aspect of the multiplicity, i.e., a specific complex of intensities, is actualized at one moment it might be the case that other aspects cannot be actualized at that very moment. My actual heart cannot be at once your heart, also, it cannot instantly turn into a liver or a kidney. Theoretically there is a virtual trajectory that may lead to the actual manifestation of the first case but then the distinction mine-yours will become obscured. In the second case, again, there are possible trajectories leading to such a transformation but what is referred to as 'instant' must depend on the manner of actualization, the materials and physical processes involved etc. If all differences were to have manifested in actuality at once, the outcome would have been only pure disorder. That we are able to experience actual order means we can imply a structure of the virtual where not everything goes, that is, though everything is expressible, not everything is fully expressed at once.

A multiplicity as an architecture of relations of difference can be actualized in myriad forms that do not resemble each other and have no structural resemblance to the virtual structure. Intensities that bring forth 'heart' can be actualized in indefinitely many actual individual hearts. These can be human hearts, animal hearts, artificial hearts, even hearts of fictional creatures with imaginary anatomies. All actual hearts are repetitions expressing multiple passive syntheses of virtual lines of developing differences. Signs like 'heart beats' or 'atrium', 'ventricle', etc. are synthesized into the sign 'heart'. In the same manner that 'step' appears between two orders of repetition, so heart can appear as a relation among a few orders of structural repetitions without having to specify an *a priori* concept. The concept that may unite all the individual instances and represent them as 'heart' is a secondary product, as already discussed.

The centrality of multiplicity is not only in the descriptive role it plays in regard to the structure of the virtual. It plays a critical role in presenting an alternative to both the Aristotelian and Platonic metaphysical systems by replacing essences and Ideas respectively (see also 4.2.3.3). It is not in the scope of this work to account for the detailed arguments mounted in favour of (or against) these replacements. In the case of essences and the whole Aristotelian system, the nexus of the argument is first the univocity of being and second the so called Copernican replacement of identity with difference. Essence is indeed the element of identity, i.e., something is what it is because of its essentiality, while difference is the element of multiplicity, i.e., something is never only what it is because of its difference, which supports the notion of mobile or nomad reality.

The case of Ideas is much more interesting, as Deleuze makes the case that the virtual is the realm of Ideas. This might seem more than a bit surprising; the whole case of Deleuzian metaphysics is accounted as an attempt to overcome the transcendent, self-identical and eternal entities that Platonic Ideas are. How come, if so, that Ideas populate the realm that precedes all actual forms of thought and this without falling back to transcendent ideal forms? As we will shortly see, Deleuze replaces the Platonic forms with mobile virtual multiplicities. The very idea of Idea is profoundly transformed.

4.2.3 Ideas in the Wild

Up to this point, we have specified the necessary structural elements of the virtual. We have drawn what virtual structure can be and how. The question still remains how progressive determinations that seem to be open-ended would bring forth actual determinations. In other words, Deleuze seeks to provide a structure which accounts for determinable differences to be determined while remaining indeterminate (Williams, 2003, pp. 138-140). He goes about this by showing how Ideas are synthesized from differences and relations between differences. Ideas in the wild comes to allude to the profound difference between Platonic Ideas, which populate a realm of pure eternal order, and Deleuze's Ideas, which populate a realm of chaotic virtuality.

4.2.3.1 Ideas are Problems

Conventionally, to have an Idea about something is being able to represent it in terms of appropriate thought forms. For Deleuze, to have an Idea about something is to infer a problem to which that something is a solution. This can be understood, at least to some approximation, from the following:

> "Ideas, therefore, present three moments: undetermined with regard to their object, determinable with regard to objects of experience, and bearing the ideal of an infinite determination with regard to concepts of the understanding. It is apparent that Ideas here repeat the three aspects of the Cogito: the I am as an indeterminate existence, time as the form under which this existence is determinable, and the I think as a determination. Ideas are exactly the thoughts of the Cogito, the differentials of thought. [...] There is neither identification nor confusion within the Idea, but rather an internal problematic objective unity of the undetermined, the determinable and determination." (Deleuze, 1994, pp. 169-170)

Following the mathematical metaphors that Deleuze is using, the undetermined is like an equation, that is, a relation between variables or lines of developing differences. Determinability means that the equation is solvable in as far as we can present particular solutions – specific objects of experience that actually express the conditions encoded in the equation. Finally, the ideal of infinite determination is to be understood as the general solution of the equation, that is, concepts that encompass all the specific objects which are the particular solutions. The example of the Cogito achieves a double goal: first, it demonstrates that the thinking subject itself is an Idea that fits Deleuze's transcendental model of Idea and its three moments, or metaphysical events. Second, it describes Ideas as the differentials of thought in the Cogito, meaning that if Ideas are the equations (i.e., problems presented as something analogous to differential equations in that they specify relations between differences), thinking is the solving (determination): coming up with particular and general solutions. More importantly, Ideas have no identity, but are only a stage facilitating the activity of determination and its products (identities as specific solutions). In this sense, Ideas are said to be internal problematic objective unities of the undetermined, the determinable and determination. Notably, objective here means a synthesis which is independent from a presupposed thinking subject. Even before we attend to the specifics of structure, we can already palpate the tensions held within an Idea between the undetermined and determination. We will see that this tension is only relaxed in actuation but is never exhausted.

4.2.3.2 Ideas are Multiplicities

Ideas are not just any equation. The metaphor is much more specific and more profound: Ideas are like differential equations as they draw relations not between variables but between *differentials of variables* or differences. The major idea that Deleuze borrows from differential calculus (see also (DeLanda, 2013, chap. 2)), is that differences reciprocally determine each other in their relations but without ever having to actually determine final values to variables:

> "Each term exists absolutely only in its relation to the other: it is no longer necessary, or even possible, to indicate an independent variable. For this reason, a principle of reciprocal determinability as such here corresponds to the determinability of the relation. The effectively synthetic function of Ideas is presented and developed by means of a reciprocal synthesis. [...] This is what defines the universal synthesis of the Idea (Idea of the Idea, etc.): the reciprocal dependence of the degrees of the relation, and ultimately the reciprocal dependence of the relations themselves." (Deleuze, 1994, pp. 172-173)

In the terms discussed above, variables are series of differences, and relations between variables – the reciprocal determinations, are intensities – the manner variables affect and are being affected by each other. Systems of reciprocally determining variables form multiplicities with specific characteristics:

> "Ideas are multiplicities: every idea is a multiplicity or a variety. In this Reimannian usage of the word 'multiplicity' (taken up by Husserl, and again by Bergson) the utmost importance must be attached to the substantive form: multiplicity must not designate a combination of the many and the one, but rather an organization belonging to the many as such, which has no need whatsoever of unity in order to form a system. [...] 'Multiplicity', which replaces the one no less than the multiple, is the true substantive, substance itself [i.e., replacing essences]. [...] Everything is a multiplicity in so far as it incarnates an Idea [i.e., all actual manifestations of Ideas are multiplicities]. [...] An Idea is an n-dimensional,

> continuous, defined multiplicity. Color - or rather, the Idea of color - is a three-dimensional multiplicity. By dimensions, we mean the variables or co-ordinates upon which a phenomenon depends; by continuity, we mean the set of relations between changes in these variables - for example, a quadratic form of the differentials of the co-ordinates; by definition, we mean the elements reciprocally determined by these relations, elements which cannot change unless the multiplicity changes its order and its metric." (Deleuze, 1994, pp. 182-183)

The definitional element added here is that an Idea is not multiplicity as such but an n-dimensional system of variables with well defined reciprocally determining relations among the differential elements of these variables. This final limitation on the number of variables and their relations makes the Idea determinable while leaving it indeterminate and inviting actual determination.

There are three conditions on the emergence of Ideas (ibid., p. 183):

1. The elements of the Idea are not sensible, conceptual or otherwise actual. They are pure virtual elements. As such, they have no *a priori* identity.

2. The elements of the Idea are determined, but only reciprocally, through their relations with each other. There are no independent elements (like independent variables in a function). The multiplicity constituting the Idea is intrinsically defined, meaning that the definition does not rely on a framework or a coordinate system which is external to the variables involved (this is further discussed in some detail in chapter 10 and see also (DeLanda, 2013, chap. 1)).

3. "A multiple ideal connection, a differential *relation*, must be actualized in diverse spatiotemporal *relationships*, at the same time as its elements are actually incarnated in a variety of terms and forms. [...] A structure or an Idea is a 'complex theme', an internal multiplicity - in other words, a system of multiple, non-localisable connections between differential elements which is incarnated in real relations and actual terms." The third condition is perhaps the most critical one. Ideas *must* be actualized. There are no transcendent Ideas that exist independently from actualization. Ideas therefore are immanent in actual manifestations. Moreover, such manifestations hold an internal correspondence, both structural and dynamic between the actual and virtual aspects. Finally, Ideas are complex themes that can be actualized in myriad different fashions.

With the definition of Ideas as the structural elements of the virtual, the whole framework of Deleuze's metaphysics becomes clear. The virtual is a vast field underlying the actual aspect of reality and intrinsic to it:

> "It is sufficient to understand that the genesis takes place in time not between one actual term, however small, and another actual term, but

> between the virtual and its actualization - in other words, it goes from the structure to its incarnation, from the conditions of a problem to the cases of solution, from the differential elements and their ideal connections to actual terms and diverse real relations which constitute at each moment the actuality of time. This is a genesis without dynamism, evolving necessarily in the element of a supra-historicity, a static genesis which may be understood as the correlate of the notion of passive synthesis, and which in turn illuminates that notion." (Deleuze, 1994, p. 183)

Three points are worth noting in this quote, which draws the blueprint of Deleuze's nomad reality. First, that genesis takes place not within the actual but between the actual and the virtual. We will return to this point in the next chapter when discussing the process of individuation. The second point is the correlation made between the virtual-to-actual genesis and passive synthesis, hinting at the contraction of differential (intensive) elements as instrumental in actualization. The third, most striking, point is that the genesis of the actual from the virtual is *a static genesis*. That is to say that all the dynamism that we observe wholly belongs to the actual where its virtual counterpart is a static pattern of becoming. The metaphysical mobility of reality is encoded in the static para-temporal virtual dimension.

4.2.3.3 Singularities and Significance

As virtual constructs Ideas are never overt. They always hide beneath their manifestations and their structure can only be inferred from their manifestations[10]. To further specify the inner structure of Ideas, it is indeed best to use the state-space metaphor as an analogy. Even for a relatively simple dynamic system it is often hard to formulate its dynamics mathematically using differential equations and even harder or impossible to solve such equations analytically in order to learn about the actual behaviours of the system. Instead, it is often possible to characterize the system by computing or inferring *tendencies* to behave in certain ways. For example, water tends to flow from higher to lower places and stops flowing at the lowest place no matter how complex the topography of a region is; hot and cold regions in a room tend to equalize their temperatures; populations grow until their environment cannot sustain growth, no matter the complex dynamics involved, etc. The behaviour of systems is governed by moving along trajectories in their state-space and the shape of trajectories is governed by what are called attractors or singularities,[11] which are like the topographic features of the state-space (for a more detailed discussion of singularities as structural features see chapter 10 section 6.2).

More generally, singularities are features of the complex relations arising between differences that constitute an Idea. These features become prominent in the course of actualization and form corresponding features in the actual systems. When

[10] This is what makes Ideas transcendental. Ideas, however, are not transcendent because they are immanent in actual manifestations.

[11] In the sense discussed here, not all singularities are attractors in the mathematical sense.

differences reciprocally determine each other, they can have a consistent relation in a certain region, e.g., while one grows the second diminishes. But when certain values are reached, the differences change their behaviour and from then on they reinforce each other; when one grows so does the second. The point where behavioural tendencies change is in Deleuze's terminology a distinctive point or a singularity (see also 4.1.2 on the passive synthesis of virtual differences). Other points that do not signify a change of behaviour are just regular points of development. All this might sound quite abstract but the underlying idea is pretty straightforward: Ideas are characterized by the distribution along the Idea's developing dimensions of points of interest, or put otherwise, their relative positioning within the multidimensional virtual spaces that Ideas are. Singularities are like topographic features of a certain territory that guide the development along trajectories. Note, however, that lines of development of differences are not metric (i.e., ordinal series of differences without a common measure) so the distribution of singularities and their spatial relations are given in topological terms rather than metric relations (DeLanda, 2013, chaps. 1-2). A metric distribution would mean that distances between singularities can be fixed and that would imply particular actualizations, in other words, identities.

The meaning of singularities is reflected in their correspondence to significant features, both structural and dynamic in actual systems, objects and processes. The manner in which Ideas are expressed in actuality is marked by either the *significance* or regularity of actual features. All turning points and events of significance correspond to singularities and their influence. Regular points along developing trajectories are only reflected in actual 'boring' or monotonous features between one singularity and another.

A simple example of such an event of significance is the phase transition of water from liquid to solid or vice versa. Below and above zero degrees Celsius water behaves pretty regularly in response to heating or cooling. It does not significantly change its physical features. But the transition from below zero to above zero and vice versa is a transformative event – a phase transition: heating or cooling will no longer change the temperature as they regularly do. Instead, liquid water turns into solid ice or vice versa. The virtual singularity corresponding to both directions of transition from liquid to solid and from solid to liquid is one and the same. It does not indicate a before or after, but only marks a turning point in the manner that certain differences reciprocally determine each other. In this sense singularities are considered atemporal (suprahistorical) virtual events corresponding to actual temporal events. Every freezing and melting event is a repetition expressing a certain Idea following a certain distribution of singularities within the Idea. A phase transition is of course a complex event. The virtual event described in this example hides a complex system of Ideas beneath it where intensities corresponding to molecular level interactions are involved and are actualized at the same time that water is freezing and melting. The macro event of freezing and melting water is a grand synthesis of repetitions of molecular events.

The example provides the rationale of why (and how) singularities are the primary manner for specifying Ideas. Ideas given in terms of distributions of singularities provide the ultimate replacement to transcendent Platonic Ideas. While regular points affirm and manifest continuity, it is singularities or distinctive points that affirm change, disruption, turning points[12] etc.:

> “Ideas are concrete universals in which extension and comprehension go together - not only because they include variety or multiplicity in themselves, but because they include singularity in all its varieties. They subsume the distribution of distinctive or singular points; their distinctive character - in other words, the distinctness of Ideas - consists precisely in the distribution of the ordinary and the distinctive, the singular and the regular, and in the extension of the singular across regular points into the vicinity of another singularity. There is no abstract universal [i.e., a platonic Idea] beyond the individual or beyond the particular and the general: it is singularity itself which is ’pre-individual’. ” (Deleuze, 1994, p. 176)

Ideas as concrete universals paradoxically weave together the concreteness of determination and the universality of the indeterminate. On one hand, Ideas are immanent in actual manifestations. If there is no manifestation there is no way to conceive of an Idea. To conceive an Idea is to bring it into being – to actualize and express it. Yet, Ideas remain universal because they can be expressed in an indefinite number of different ways. Actual expressions are solutions that point back to the problems (Ideas) they solve but they never exhaust the problem. Complete determinations in the form of actual instantiations of variables or constant relations are possible only when the problematic of the Idea has a closed definition (see further: (ibid., p. 171)). As will be discussed in 4.2.3.4, Ideas are interconnected and open and therefore complete determinations are only approximations under limiting conditions. Metaphysically, there are no final solutions. There is an inherent incompleteness in reality.

An additional feature of this construction of Ideas is that significance and its correspondence to the distribution of singular points replace the role of essences (in the Aristotelian sense) in thought:

> “The problem of thought is tied not to essences but to the evaluation of what is important and what is not, to the distribution of singular and regular, distinctive [singular] and ordinary points, which takes place entirely within the inessential or within the description of a multiplicity [the virtual], in relation to the ideal events which constitute the conditions of a ’problem’. To have an Idea means no more than this, and erroneousness or stupidity is defined above all by its perpetual confusion with regard

[12] Interestingly, cognitive systems are tuned exactly to the expression of singularities.

to the important and the unimportant, the ordinary and the singular." (Deleuze, 1994, pp. 189-190)

With Ideas and singularities, it now becomes clearer how Deleuze addresses thought beyond the human condition. His construction of Ideas does not presuppose a thinking subject or a particular manner of thinking. Ideas are rather the fundamental constituents of reality and it is not anyone's reality but reality as such. Later we will see that thought itself is reciprocally meant in a sense much wider than a process that takes place in brains.

4.2.3.4 The Plane, Adjunct Fields, Assemblages

All Ideas in the virtual are interwoven together into a construct termed *the plane of consistency* (Deleuze and Guattari, 1987, pp. 9,69-73,), (Parr, 2010, pp. 204-206). The word 'plane' need not be taken here in its literal geometrical connotation. It is rather understood under the principle of univocity, namely, that metaphysically speaking there are no hierarchies of being among Ideas, though there are structural hierarchies expressed in actuality. Every Idea can envelope or be enveloped in other Ideas in various configurations. The word consistency indicates that Ideas are interconnected and have no relations of contradiction or negativity among them.

Series of progressive determinations (variables) which are the constituents of Ideas each participate in many Ideas and by that connect Ideas together into a tightly woven virtual fabric. The *adjunct fields* of an Idea draw a certain contour – a kind of associating network that affects the manner by which the actualizations of Ideas take place and the dynamism involved. To understand the concept and how Ideas connect and envelope each other, it is best to use an example. A knife is just a piece of metal if it is not in the course of cutting or being sharpened. A knife can be used as a door stopper, or an element in a sculpture etc. In all these manifestations the shape of the knife, which does not change much, is an expression in form of a certain Idea. But how an individual knife interacts with other individuals is no less instrumental to which Ideas are expressed. The adjunct Ideal fields of the Idea 'knife' is all the Ideas that connect to it, share some (or all) of its dimensions, and by that affect its ongoing actual expression. Notice that expression is not only a matter of form but also a matter of significance or meaning within a certain configuration or context. More generally, every actual individual is expressing a number of Ideas, depending also on its relations and interactions with other individuals. The Ideas involved indeed define certain properties of actual individuals but actualization is never local. The properties of every individual always depend on the ways it affects and is being affected by other individuals.

Understanding the productive dynamism involved in the actual expression and manifestation of Ideas starts from recalling that the virtual dimension of reality is interconnected and therefore *all the Ideas* can be said to participate in any actual state of affairs. Yet in every actualization, when observation is narrowed to a particular system, object, process or state of affairs, it is always the case that certain Ideas are highlighted and distinct while other Ideas remain obscured. This highlighting and obscuration is due to actual interactions taking place among individuals. Observation is itself an actualized interactive process that involves an observer, an object and a manner of observing (how differences in the observed make differences for the observer). Observation itself, therefore, highlights certain Ideas while obscuring others. This is why observation inherently expresses a unique individual (and individuating) perspective. The innocent looking cake slicer can become an instrument of a gruesome murder, one's medicine is another's poison, one's lover is another's sworn enemy etc. It all depends on actual individual assemblages (how individuals connect and interact) and the manner the underlying Ideas are connected. The whole dynamism of actual reality expresses at every moment the vast underlying virtual multiplicity as a whole. Hence the plane of consistency. To illustrate further, actual reality is sort of holographic in the sense that each individual expresses the whole of the virtual but with different degrees of clarity.

Certain actual manifestations gravitate towards converging on certain Ideas, i.e., the singularities of the Idea become prominent in their effects and by that bring forth correspondingly distinct individuated states, e.g., the negative response of financial markets across the world (the determining process) deepen the overall sense of global recession (the Idea becoming highlighted)... In contrast, there are manifestations moving in an opposite direction, away from certain Ideas. By so doing, they weaken the distinctiveness of certain states or systems and may even bring about their disintegration or dissolution. For example, recent rises in nationalistic sentiments (process) cause the loosening of member states' commitment to the European Union and as a result the EU's coherency as a unified entity (the Idea dissolving) becomes vague. The corresponding virtual trajectory in the latter case is termed *line of flight* (ibid., pp. 144-146). Lines of flight are intensities developing away from an Idea towards other Ideas in its periphery and further. These drive actual processes of disintegration and reorganization of actual systems.

When actualization develops along lines of convergence, the Ideas expressed by the actual individuals become distinct. Behaviours seem ordered, coordinated and predictable following lawful changes. The Idea(s) prominently expressed then hide the virtual interconnectedness underneath them; inner tensions and disturbances are downplayed and marginalized. There is an overall increased sense of order and coherency. When actualization develops along lines of flight, the Ideas expressed by actual individuals become less distinct. What is observed in such cases is a state of affairs which is closer to the virtual: things are more confused and less clear and coherent. Individuals seem interconnected and highly sensitive to interactions while inner tensions, differences and disturbances are highlighted. One can then see more clearly the underlying virtual fabric of reality[13]. These processes of actualization are

[13] A fascinating description is given in (Deleuze and Guattari, 1987, chap. 6) with the provocative title: "How Do You Make Yourself A Body Without Organs".

also termed processes of *territorialization* and *deterritorialization*[14] respectively (Parr, 2010, pp. 274-276) as if Ideas populate certain territories within the actual and the contours of these territories undergo processes where they become more or less pronounced.

4.3 Individuals – Nomad Structures

The final section of this chapter complements the rest of it by addressing the structure of the actual aspect of reality. While the virtual is pure structure, the actual is where dynamism and change are actualized. Individuals are the elements of actual reality. These are unique objects, systems, processes, states of affairs, organisms, relations, thoughts and sensations. They are the actual players in the drama of existence. They are not beings but rather becomings; they exist not as what they are but as what they continually become – carriers of difference. Critically, individuals are the determinations and expressions of Ideas. It is as far as determination reaches, which also reminds us of the fundamental encounter that forces thought. Individuals are the products of this very encounter.

> "Intensity is the determinant in the process of actualization. It is intensity which dramatizes. It is intensity which is immediately expressed in the basic spatio-temporal dynamisms and determines an 'indistinct' differential relation in the Idea to incarnate itself in a distinct quality and a distinguished extensity." (Deleuze, 1994, p. 245)

> "The real individual is set in motion by sensation, expresses Ideas, falls into actual identity. It is a take on the whole of Ideas, bringing some into greater clarity, throwing others into obscurity." (Williams, 2003, p. 185)

For Deleuze, individuals are not derivatives of more general hierarchical categories of essences or concepts. Individuals are unique bottom-up creations. "set in motion by sensation" should be read as brought forth by affective intensities proper to the actualized system, e.g., differences in the frequencies of gene expression in populations of organisms that drive speciation processes, changes in temperature that drive phase transitions in matter, chemical gradients that drive embryonic development, etc. Continuing the line of thought developed in 4.2.3.4, individuals are nexus of connectivity. Individuals are always expressions of the whole of the realm of Ideas. By highlighting certain Ideas and obscuring others, an individual manifests

[14] The new terms mentioned in this subsection are prominent throughout the text of *A Thousand Plateaus* (Deleuze and Guattari, 1987). Following Deleuze's philosophical method, the authors avoid conceptual definition. Instead they only highlight how these terms interconnect and are used within the context of many other terms. I have provided a complementary reference to dictionary definitions but these should be taken as partial and highly simplified and in some sense antithetic to the whole methodical approach.

an asymmetry of expression, that is, an asymmetry in the clarity and coherency of expression. This is how individuals acquire identity and manifest a unique perspective on the whole. The unique identity and asymmetric perspective of each individual always involves the assemblage it forms by interacting with other individuals. This dependence on connections with 'other than itself' entities makes the identity and perspective associated with individuals incomplete and impermanent. These are the marks of the intrinsic openness of individuals.

Expressing virtual intensities, individuals are intrinsically mobile (nomad) entities. The identity and perspective they manifest are fleeting and only apparent (in the sense of being secondary to the metaphysical element of difference). Individuals are inseparable from a process of individuation that brings them forth. In some sense they are hybrid in-between entities that belong neither entirely to the actual nor entirely to the virtual and are neither fully formed products nor productive processes per se:

> "The individual thus finds itself attached to a pre-individual half which is not the impersonal within it so much as the reservoir of its singularities. [...] [W]e believe that individuation is essentially intensive, and that the pre-individual field is a virtual-ideal field, made up of differential relations. [...] Individuation is the act by which intensity determines differential relations to become actualized, along the lines of differenciation and within the qualities and extensities it creates." (Deleuze, 1994, p. 246)

> "The individual is neither a quality nor an extension. The individual is neither a qualification nor a partition, neither an organization nor a determination of species. [...] The determination of qualities and species presupposes individuals to be qualified, while extensive parts are relative to an individual rather than the reverse. [...] It is because of the action of the field of individuation that such and such differential relations and such and such distinctive points (pre-individual fields) are actualized [...] As a result, they then form the quality, number, species and parts of an individual in short, its generality." (ibid., p. 247)

What is important to note here is that once extensities and qualities are actualized, they are representable and the individual loses its ultimate uniqueness and gains a generality, that is, it can be recognized, compared, qualified etc. Deleuze goes to great lengths to delineate individuals as such and present them as the loci of individuation. The specifics of the relations between the virtual and the actual and the manner by which individuals are brought forth is the topic of the next chapter.

Chapter 5

Individuation

Shifting from being to becoming, from identity to difference, from object to process and from the individual to individuation mark the attempt of both Bergson and Deleuze to account for the origins of thought and in particular to trace such origins beyond the human condition and the presupposition of a thinking subject.

This chapter complements the previous one, describing the genesis of actual individuals in the Deleuzian metaphysical system. Deleuze's theory of reality constituting both actual and virtual dimensions is clearly an evolution of Bergson's earlier ideas. But it was Deleuze's contemporary Simondon that inspired his theory of individuation (Iliadis, 2013). Here we explore the concept of individuation following its line of development from Simondon[1] to Deleuze and finally to an attempt to deploy it as a metaphysical foundation of self-organization.

5.1 Simondon's Theory of Individuation

5.1.1 Being and its Genesis

Simondon's point of departure in developing his theory is a critique on the reality of being. The two theories he examines are the substantialist and hylomorphic approaches to the genesis of being. In the substantialist approach, there is no genesis at all. Being is a consistent unity, given to itself, uncreated and resistant to that which it is not. The hylomorphic approach posits individuals as form being impressed on matter (Simondon, 2009). Common to these two approaches is the presumption of a principle of individuation which is anterior to the individuation itself and explains how it takes place. In both cases the point of departure is an already constituted individual from which the investigation goes backward towards a presupposed principle of individuation which is already an individual. "What is postulated in the search for the principle of individuation is that the individuation has a principle." (ibid., p. 4). If there is a principle, individuation is merely the unfoldment of one individual into another. Similar to how conventionally difference is only defined in

[1]The section on Simondon's theory of individuation is based on a translation of the first part of Simondon's introduction to his book'*L'individuation psychique et collective*, and presents only the major metaphysical concepts of his work.

terms of the identities that precede it and follow it, so the kind of ontogenesis understood as the unfoldment of an individual into another one subjugates the process to these individuals. Simondon's programme is to reverse this relation:

> "We would like to show that the search for the principle of individuation must be reversed, by considering as primordial the operation of individuation from which the individual comes to exist and of which its characteristics reflect the development, the regime and finally the modalities. The individual would then be grasped as a relative reality, a certain phase of being that supposes a preindividual reality, and that, even after individuation, does not exist on its own, because individuation does not exhaust with one stroke the potentials of preindividual reality" (Simondon, 2009, p. 5)

In order for a process of individuation to precede any individual, three conditions must follow: first, there is a preindividual reality, or a field of individuation which is not preceded by any individual. Second, that individuation does not stop. It cannot stop because if it does, it means that the preindividual reality is exhaustible and therefore after a finite process we will be left only with the final individual products that will continue forever after. If individuation becomes primary and individuals secondary, their reality becomes relative and impermanent; they never stop to individuate. Third, similar to Deleuze's idea of unilateral determination, Simondon argues that individuation cannot bring forth individuals in a vacuum. Instead, individuation actually brings forth a partitioned existence of an individual and its environment or context of existence (it is the individual separating itself from its background). To fulfil these conditions a new metaphysical system needs to be created where no principle of individuation is already encoded.

5.1.2 Being and Becoming

The metaphysical innovation that Simondon brings is that individuation must take place *within* being. It designates a becoming within being – not a specific becoming but the becoming of being as such. For this, Simondon 'stretches' being beyond the rigid definitions prescribed by the substantialist and hylomorphic systems and makes it inherently *mobile and incomplete*:

> "*Individuation is thus considered as the only ontogenesis, insofar as it is an operation of the complete being.* Individuation must therefore be considered as a partial and relative resolution that occurs in a system that contains potentials and encloses a certain incompatibility in relation to itself – an incompatibility made of forces of tension as well as of the impossibility of an interaction between the extreme terms of the dimensions." (ibid., p. 5)

A complete being, according to Simondon, contains a preindividual being, an individuated part and a process of becoming – individuation (the specific terms of the process are further discussed in 5.1.3). The most significant characteristic of this notion of being is that it continually "falls out of phase with itself". This somewhat vague phrase encodes quite a few ideas that were already discussed. In order to fall out of phase with itself, being must be heterogeneous – having more than one possible phase (states) and mobile – in movement among its internal phases. Finally, the phrase also indicates a relation of interiority within being as it must persist in itself while falling out of phase with itself. In somewhat different terms, the preindividual (the indifferent) has no phases, and what Simondon terms becoming is the division of being into phases which can be thought of as (partial) determinations *within* being. In yet different terms, Simondon draws a kind of a metaphorical cybernetic circuit: as long as being is identical to itself, it is in a stable phase. But once it spontaneously falls out of phase (because of the 'noise' of the preindividual) with itself, the resulting difference or 'error' drives an individuating change that brings it back into stability but in a different phase and then again... Notice, however, that Simondon's metaphysical schema does not involve an explicit virtual element, although there is an implicit virtuality in the preindividual. The preindividual cannot possibly make being to fall out of phase with itself in all possible manners at once. Instead, its potential unfolds progressively and drives individuation in a not entirely random (indifferent) manner. This hints to inherent heterogeneity and the presence of intensities within being. The virtuality implied by Simondon, therefore, can be said to be structured and not entirely indifferent. This is why Simondon can be rightly considered as an harbinger of Deleuze's theory of individuation. Nevertheless, as we will see, in contrast to Deleuze, Simondon gives individuation a causal description.

5.1.3 The process of Individuation

Individuation is a process that bring forth individuals. It is clear that Simondon is using a conceptual framework borrowed from dynamic systems theory and especially far from equilibrium systems in order to articulate how processes of individuation work. Individuation, according to Simondon, is driven by unresolved tensions existing in problematic situations. "It can only be understood on the basis of the initial supersaturation of being – without becoming and homogeneous[2] – that then structures itself and becomes, bringing forth individual and environment, according to becoming, which is a resolution of the initial tensions and a conservation of these tensions in the form of structure." (ibid., p. 6) In other places Simondon alludes to an unstable meeting point between reservoirs held at different energy levels or potentials ("orders of magnitude") and where the spontaneous ensuing equalization of the potential differences engenders a process of self-organization that brings forth a mediating structure (e.g., the phenomenon of convection, hurricanes, etc.).

[2]Notice that homogeneity here relates to actual form. The process of individuation and self-organization that ensues clearly hints towards the virtual heterogeneity mentioned above.

The core idea behind these analogies is solving the problem of how stable entities may arise within a flow of change. It is this idea applied to an extended notion of being that constitutes Simondon's metaphysical approach. The problematic situation, that is, any situation where incompatibilities between elements invite resolution through change, is the model ground of individuating processes. At the extreme Simondon speaks of disparate orders where initially no communication exists between elements. In such cases, individuation also means establishing a medium of communication and exchange (e.g., learning a language in order to cooperate with fellow humans).

As was mentioned in 5.1.1, there is no *a priori* principle as to how individuation proceeds in specific cases. It can be said that individuation itself individuates and brings forth its own individual principle while taking place. Consequently, being does not indeed have a constitutive principle of identity in itself. It is inherently different from itself, yet it is said to *be* in the same sense in all cases and in all its phases, i.e it is univocal. Lacking a principle, individuation cannot be represented. It belongs to the realm of thought sans image:

> "We cannot, in the common understanding of the term, know individuation, we can only individuate, individuate ourselves, and individuate within ourselves. This understanding is–at the margins of what is properly considered as knowledge–an analogy between two operations, a certain mode of communication." (Simondon, 2009, p. 13)

There can be no knowledge of individuation itself. First because there is neither a consolidated object of knowledge waiting to be discovered nor a knower with a consolidated capability of knowing. Knowledge is said to arise as a resonance or communication between two (or more) individuating systems. It is a formative relation of communication. Communication as Simondon is using the term (further discussed in 5.1.3.3), resonates with Deleuze's concept of intensity. They actually use very similar metaphors and analogies to describe the respective terms.

5.1.3.1 Metastability

Central to how the problem of the relation between individuation and individuals is solved is the concept of metastability:

> "Individuation has not been able to be adequately thought and described because previously only one form of equilibrium was known–stable equilibrium. Metastable equilibrium was not known; being was implicitly supposed to be in a state of stable equilibrium. However, stable equilibrium excludes becoming, because it corresponds to the lowest possible level of potential energy; it is the equilibrium that is reached in a system when all of the possible transformations have been realized and no more force exists. [...] Antiquity knew only instability and stability,

> movement and rest; they had no clear and objective idea of metastability. In order to define metastability, the notions of order, potential energy in a system, and the notion of an increase in entropy must be used. In this way, it is possible to define this metastable state of being–which is very different from stable equilibrium and from rest–that Antiquity could not use to find the principle of individuation, because no clear paradigm of physics existed to help them understand how to use it." (ibid., p. 6)

In simple terms, being is metastable and not stable. Therefore it contains a transformative potential which is actualized in a continuous process of individuation. A notable difference between physical systems and being is that the potentials that drive self-organization of systems originate from the interactions between a system and its environment. In other words, for a system to be metastable it must be an open system. Being, on the other hand, was considered a stand-alone element. It now becomes clear why in order to make being metastable, Simondon includes in the individuating being both the individual and its environment. This way the individuating forces remain within being.

To better understand metastability, it is best to use the terminology of dynamic systems theory. The states of a given system can be mapped into an energy plane representation where each state is represented by a point on a N-dimensional plane[3] and is assigned a scalar number designating the energy of the system at that state. A stable state of the system is a state characterized by a low energy value relative to all its neighbouring states. If the system is perturbed from a state of stability it will often (depending on the size of perturbation) reach a state of slightly higher energy and will tend to return to the initial state of lower energy, releasing to the environment the extra energy gained by the perturbation. For example, a ball resting at the bottom of an inclined plane (state of stability) when pushed upward (perturbation), will roll down to the bottom, releasing the extra energy it gained from the push by moving down. A metastable system is a system with a number of local energetic minima. Given strong enough perturbations a metastable system may move among states of local stability and hence the designation that implies that no single state is truly stable.

Conventionally, the topography of the energy landscape is given and the system dynamics only moves among the already determined set of stable states. This representation, however, will only fit an already individuated system. When it comes to being, Simondon's notion of metastability significantly departs from this formal scheme in that the relations between variables in a preindividual condition are not yet determined and the topography of the whole landscape is undetermined too. In the course of becoming, the individuating topography of the preindividual landscape gains local determinations, i.e., becomes more or less individuated. Following

[3]The number of dimensions corresponds to the number of state variables which are required to define each state.

such determinations the topography settles into more or less stable shapes as the state variables reciprocally determine their relations.

The metastable being is not determined *a priori* but rather individuates along with its structure in a sequence of transitions. Metastability therefore does not mean multiple points of stability but rather a developing topographic configuration of such points. Clearly, this description resonates with Deleuze's description of Ideas. Both are using similar analogies in describing a mobile existence punctuated by relatively stable and persistent structures and properties. Another significant similarity is that individuals carry with them the transformative potential of the preindividual and the continuation of individuation in the same manner that Deleuze's virtual aspect of reality is inherent to actual individuals:

> "An individuation is relative, just like a structural change in a physical system; a certain level of potential remains, and further individuations are still possible. This preindividual nature that remains linked to the individual is a source for future metastable states from which new individuations can emerge. According to this hypothesis, it would be possible to *consider every true relation as having the status of being, and as developing itself within a new individuation.* The relation does not spring up from between two terms that would already be individuals; it is an aspect of the *internal resonance of a system of individuation*, it is part of a system state." (Simondon, 2009, p. 8)

Relations, for Simondon, individuate as an intrinsic part of being and are not considered to exist outside of being or between beings. The kind of relation that Simondon has in mind is a relation of interiority:

> "[...] [I]t is possible to understand relation [internal to being] as the non-identity of being to itself–as the inclusion in being of a reality that is not only identical to it–so that being, as being, before all individuation, may be understood as more than unity and more than identity." (ibid., p. 10)

Here, Simondon's influence on a few of Deleuze's major ideas is even more apparent: intensities in the Deleuzian scheme seem to be the virtual counterpart to Simondon's individuating relations.

5.1.3.2 Transduction

Transduction is the term Simondon gives to the actual process of individuation. Transduction shares many of the features normally associated with processes of self-organization. The difference lies in that while self-organization commonly describes the convergence of trajectories towards attractors within an already configured state-space of a given system, transduction does not presume such an *a priori* configuration, which is indeed characteristic only of already individuated systems. What normally makes self-organization significant is its final state – the organization. In contrast, transduction is open-ended; organization is only considered an intermediate phase within transduction:

> "By transduction we mean an operation – physical, biological, mental, social – by which an activity propagates itself from one element to the next, within a given domain, and founds this propagation on a structuration of the domain that is realized from place to place: each area of the constituted structure serves as the principle and the model for the next area, as a primer for its constitution, to the extent that the modification expands progressively at the same time as the structuring operation." (ibid., p. 11)

The novelty in the concept of transduction is the interplay or exchanges between structure and operation. It is a process of progressive co-determination where each structure mediates two successive operations and each operation mediates two adjacent structures (Combes and LaMarre, 2013, pp. 14-15). Each structure in the series constrains the operations that can immediately follow. Each operation constrains the transformation of the current structure into a new one. Every intermediate structure is a partial resolution of incompatibility in the initial problematics that drive individuation but it is driven away from its temporary stability as long as other tensions are not exhausted. Remarkably, transduction can be considered the blueprint of many open-ended formative processes e.g.:

- general computation:
  $(Code + Data) \rightarrow Execution \rightarrow (Code + Data)' \rightarrow \ldots,$
- evolutionary processes:
  $Organism \rightarrow Variation \rightarrow Selection \rightarrow Organism' \rightarrow \ldots,$
- cognitive processes:
  $Environment \rightarrow$
  $Cognition((Perception + Memory) \rightarrow (Action + Memory')) \rightarrow$
  $Environment' \rightarrow \ldots$, etc.

Transduction processes can of course take place at many scales simultaneously, driving complex individuations (e.g., elements at certain scales are stable while elements of other scales are changing). Simondon's world is a complex world where both structure and mobility partake in being and are inseparable:

> "In a certain sense, it could be said that the only guiding principle is that of the conservation of being through becoming; this conservation exists through the exchanges between structure and operation, proceeding by quantum leaps through successive equilibriums." (Simondon, 2009, p. 6)

The progress of transduction circumvents the need for an overarching principle of individuation in that each transition is in fact a local determination that need not depend on structures or operations beyond the immediate one. At every single 'leap' the current structure (or operation) is not the final determinant because the preindividual element reintroduces some 'noise' (indifference) into the next determination. Equilibrium states differ from the rest only in their lessened sensitivity to the preindividual but the effect is ever present.

5.1.3.3 Information

Information plays a critical role in individuation and in Simondon's philosophy in general (see comment 19 in (Simondon, 2009, p. 15)). Simondon's concept of information is very different from the conventional understanding of information as the reproduction of messages between a sender and a receiver (Shannon, 2001). Information has to do with relations but with formative relations and not with already formed ones. Information is a process of *establishing communication* where initially there is none:

> "[I]nformation is never relative to a unique and homogeneous reality, but to two different orders that are in a state of [disparateness]; information, [...] is never available in a form that could be given; it is the tension between two disparate realities, it is *the signification that will emerge when an operation of individuation will discover the dimension according to which two disparate realities may become a system*. [...] [Information] is that by which the incompatibility of the non-resolved system becomes an organizing dimension in the resolution; [...]" (Simondon, 2009, pp. 9-10)

Information is not a term such as a message or its physical manifestation but a process taking place between disparate orders or elements in the course of them becoming a system (within being). Communication is established in the individuation of signification – the means of exchanging meaning. When such significations stabilize, they constitute a medium of coordination for the disparate elements and these establish meaningful individuated interactions. By that, the elements and their interactions become an individuated system. Again, it is important to note that the elements brought into communication are themselves individuating in parallel and are becoming consolidated individuals while establishing communication. The whole system can be seen to differentiate internally in the course of its individuation.

The significations and the manner by which they are carried among the individuated elements within the system e.g., body gestures, voices, linguistic utterances, electronic signals, chemical signals etc. are not separable. Information as conventionally understood is merely an abstraction of only one aspect of communication. It abstracts away both the means of communication and the meaning of the messages. It is easy to see how Simondon's concept of information is applied to language. Language is not just a message passing protocol but an individuating medium which is constantly adaptive and evolving to fit changing circumstances. The signification of words and phrases is sensitive to the problematics of situations and the tensions involved in them. Language is an informational process, not because it facilitates communication using already individuated messages but primarily because it establishes communication in situations of incompatibility and disparateness. This is done by continually individuating signification within language.

5.1.3.4 Levels of Individuation

Simondon describes three levels of individuation that are fundamentally different in terms of their complexity. The first level is the individuation of physical systems (exemplified by the crystallization out of a supersaturated solution). The second level is the individuation of living systems (vital individuation) and the third level is psychic-social individuation, which is resolved only within a greater collective body. This categorization reflects degrees of complexity that may be extended beyond the specific domains explored by Simondon. The defining characteristic of physical individuation is that it takes place on the surface that distinguishes the physical system from its environment. Vital individuation takes place within the living system as well as on its surface. It is as if a living system contains a plurality of physical systems internal to it, each undergoing individuation in relation to an environment internal to the organism as well. Nevertheless, in vital individuation the contour of the organism remains more or less distinct. The psychic-social individuation is another stage of increased complexity: psychic individuations are taking place within a collective social individuation. The additional complexity arises because in this case the psychic preindividual opens into the collective preindividual (termed *transindividual*). As a result there is a process of co-individuation as the psychic problematic is resolved via the collective individuation (ibid., p. 9). The third individuation comes to account for the fact that the psychological characteristics of persons individuate in relation to and as an organic part of the individuation of the social body they belong to. Considering complex systems, these categories indeed cover a very broad span of phenomena, yet there is no solid reason to restrict the general process of individuation to just these three categories. More complex instances of individuation may span across and involve multiple scales.

5.2 Deleuze's Synthesis of the Sensible

In Deleuze's metaphysics, a theory of individuation needs to address the problem of how virtual differences account for actual events and processes. Framing the question more precisely: how does a dynamic world of actual individuals correspond to the virtual world of Ideas? The apparent difficulty of the problem lies in the virtual aspect of reality being purely structural and causally sterile. It cannot cause anything to happen and moreover it is absolutely static ("This is a genesis without dynamism..." see quote on page 88). Virtual existence must be understood as atemporal, and individuation in Deleuze's theory, unlike Simondon's concept, extends between the atemporal and the temporal (an element of supra-historicity). In individuation, time itself individuates. Nevertheless, it is Deleuze's claim that the actual dimension is wholly conditioned by the virtual one:

> "Every phenomenon refers to an inequality by which it is conditioned. Every diversity and every change refers to a difference which is its sufficient reason. Everything which happens and everything which appears is correlated with orders of differences: differences of level, temperature, pressure, tension, potential, difference of intensity." (Deleuze, 1994, p. 222)

To understand this claim and its support we need to better understand the kind of explanations Deleuze has in mind.

5.2.1 Transcendental versus Causal Explanations

Conventionally, we explain the existence of something by tracing prior conditions that are necessary and possibly sufficient to its existence. If the existence of a set of conditions X warrants that Y necessarily follows, then X is considered to cause Y and is the reason for Y to be the case. But causation is not a binding logical relation. Y is not logically deduced from the existence of X but rather inferred by X based on past experience. In other words, the connection of Y to its causes is a habit, or a repetition as discussed in 4.1.2. In this sense, causes are necessary but not sufficient reasons. X is external to Y and there is always an indefinite chain of causes and effects between X and Y. Causative explanations are extremely useful but fall short of explaining anything irregular, unique, or creative.

Causative explanations explain actual existence in terms of other actualities and by so doing remain at the level of appearances. It is not that causative explanations of reality are wrong. They are simply superficial and insufficient (see discussion in (Bryant, 2008, pp. 226-232)). The quote from Deleuze given above clearly states that the metaphysical theory he suggests does not lend much significance to causative explanations and instead finds the sufficient reason of everything that actually exists in its corresponding virtual aspect (more specifically in intensive differences). This is far from being intuitive, especially if one is bound to think in terms of identities.

As already discussed in 4.3, the elements of the actual are individuals, each unique and singular. Individuals cannot be caused in the conventional sense because they are never the same, while the principle of causation is grounded in the repetition of the same (habits). A causative explanation, therefore, cannot be based on singular cases. Since individuals are always different, they cannot causally explain one another. This is why if we consider an actuality made of individuals, causative explanations are necessarily mere superficial generalizations achieved only by averaging differences out and positing sameness prior to repetition.

By now we understand that the virtual cannot be said to *cause* the actual either. The sense in which virtual intensive differences are the sufficient reason of individuals is very different. Actual individuals are *expressions* of virtual differences immanent in them. Virtual differences can never be sensed directly, they can only be expressed. The actual aspect of reality is a dimension of expression that hides beneath it everything that can be expressed. Using the terminology developed in chapter 3, reality has dimensions of exteriority (actual) and interiority (virtual). Expression is the exteriority of things. It is the manner of their appearance in relation to other things, the way they affect (and are affected) externally. Virtual Ideas belong to the interiority of things, their 'in itself' dimension. In this sense, expression is nothing other than the exteriorization of interiority. Explaining the actual in terms of expression and expressed is a transcendental explanation simply because the sufficient reason for everything actual is inaccessible to direct experience. While causative explanations always refer to reasons external to the thing being explained, transcendental explanations refer only to reasons that are intrinsic (interior) to the thing being explained. Individuals are explained in their own virtual terms, and in these terms alone, their existence refers to difference as their sufficient reason[4]. To further clarify how this sufficient reason proceeds from difference to actuation, Deleuze writes: "[T]he essential aspects of sufficient reason – determinability, reciprocal determination, complete determination – find their systematic unity in progressive determination." (Deleuze, 1994, p. 210) All three terms were discussed in chapter 4. Differences imply determinability and reciprocal determination brings forth the whole structure of the virtual as a plane of enmeshed Ideas. Complete determination is what takes place in individuation as the actual expression of Ideas in individuals. The whole unfoldment from virtual differences to expression is termed progressive determination or simply becoming.

All that actually exists, whether static or dynamic (in relative terms), are expressions. The proposition X is the cause of Y is itself an expression of certain virtual differentiations and their corresponding actual individuations. More specifically, $X \rightarrow Y$ (read as Y always follows X) is a repetition related to a different order of repetition $XY, XY, XY \ldots$ that constitutes a habit. It can be said that every causative relation is a passive synthesis of determinations, as discussed in 4.1.2.

Consider for example how facial expressions correspond to experienced emotional states. In the actual dimension we have individual emotions expressed in the psychic experiential domain and individual facial expressions expressed as the movement from one configuration of facial muscles to another. The corresponding virtual dimension involves two major Ideas: the Idea of emotion and the Idea of face shape.

Specific emotions psychically experienced such as joy, surprise, fear etc., or even complex combinations of emotions, e.g., thrill as a combination of fear and joy, are

[4]The being of individuals is inseparable from their becoming (individuation); in their interiority they always differ from themselves.

all actual individuated expressions of passive syntheses, i.e., integrations along trajectories belonging to this Idea. Moreover, certain trajectories within the Idea can reach bifurcation points and guide unstable individuations of chaotic emotional states highly sensitive to minute changes in the organism. Note that it is the distribution of singularities of this Idea that delineate and guide the passive syntheses along these trajectories and the corresponding individuations. There is nothing emotional in the Idea itself, only reciprocally determining relations of differences. There is no dynamism in the Idea either. Only via their individuation in some actual domain, do virtual emotions actualize in distinct individual manifestations. If there is no such expression, nothing changes in the virtual dimension. The Idea of emotion still remains the virtual structure of all possible emotions but none is distinctly expressed. Without expression, the virtual Idea is just a multiplicity with no concrete features other than its singularities – it remains preindividual. It is just lost in the vast enmeshed multiplicity of all Ideas. A similar correspondence exists between the Idea of face shape and actual individuated facial expressions. For the Idea of face shape to be individuated means that its virtual trajectories are expressed in actual movements of facial muscles. The interior differences in the Idea are exteriorized in muscle movements.

Between these two Ideas there is an intensive relation. This intensive relation is itself a series of differences that hides beneath it quite a few other intensities, e.g., there is an intensive relation between the Idea of face shape and another Idea of muscle groups tensing and relaxing together. There is another intensive relation between this tensing and relaxing and patterns of neural triggers and so on. The point is that all these configurations of intensities are synthesized into a series of intensities between the Idea of emotion and the Idea of facial shape. This intensive difference means that determinations in the former series affect the determinations in the latter (and vice versa but not necessarily symmetrically so). In a similar manner it can be explained how the Idea of emotion is also intensively related to other possible manifestations, e.g., psychic experiences of emotional states.

It is such virtual intensive relations between Ideas that find expression in what we usually observe as actual causative relations. When we observe both experienced emotional states (psychic individuation) and facial expressions (physical individuation), we might figure after many observations (repetitions) that certain facial expressions correlate to certain emotional experiences or even are caused by these emotional states (e.g., if the first consistently follows the latter). But such causative relation is merely a superficial explanation. In fact the repetition of such correspondence – what constitutes it as a psycho-physical habit – is rooted in the virtual Idea of emotion, the intensive relations it holds with other Ideas and the individuations it undergoes in different domains (only one of which is facial expressions). What we actually see are expressions in multiple domains having a single virtual Ideal root.

In the terminology of Simondon, the orders of experienced emotional states and that of facial expressions are initially disparate orders. If there is no individuation, no communication is established and therefore no correspondence. This is a seemingly simpler description but it only hides the details of how Ideas are interconnected. Individuation is exactly the process that establishes or progressively determines a system of correspondences (communication) between the said orders. The details of this process is further discussed in 5.2.2.

Everything experienced, sensed and observed is never entirely what it is. It is merely an expression of something which has indefinitely many other expressions depending on circumstances. Expressions are intrinsically incomplete and impermanent, being the fabric of a nomad reality. In other words, individuals possess depth – a virtual depth of what they can become. It is indeed the Idea that determines what the body can do, but the Idea is inexhaustible in terms of its manners of expression. In this sense existence is open-ended; things have an inexhaustible and largely unpredictable variety of expressions depending on their interactions. They can mean very different things under different circumstances. Contrary to causal explanations, transcendental explanations of individuals highlight their significance, that is, the Ideas they express. As already mentioned in 4.3 individuals are always expressions of all the Ideas at once but to different degrees of clarity and obscurity. The significance of an individual is therefore in the selective expression of Ideas. Which Ideas are clearly expressed has to do (as illustrated by the example above) with varying configurations of intensities (Deleuze, 1994, pp. 252-253).

5.2.2 The Synthesis of the Sensible

Thought which is not subject to the dogmatic image of thought is driven by sensation. Deleuze hypothesizes a profound connection between thought and the static genesis taking place between the virtual and actual aspects of reality. It is not the thought of a human person however; it is thought beyond the human condition – thought as a metaphysical event. The sensible or that which is given to sensation is the counterpart of expression. If the expression of X is how it can affect other actualities, the sensibility of X is how it can be affected by other actualities. Expression is therefore the sensible for the other (not for itself). The whole schema of individuation can be concisely and elegantly put as follows:

> "The real individual is set in motion by sensation, expresses Ideas, falls into actual identity. It is a take on the whole of Ideas, bringing some into greater clarity, throwing others into obscurity. The real individual is driven by sensations that signify a reconfiguration of intensities, a change in which intensities envelop others and which are enveloped[5]. It is the site of creation, movement in Ideas and a reconfiguration of intensities expressed in the destruction of the identity of an actual thing and the

[5]The term envelop and enveloped means the terms of the enveloped series are contracted into the terms of the enveloping series. As a reminder, contraction is the passive synthesis of a number of differences into another difference within which they form an indivisible whole while also remaining plural. See (Deleuze, 1994, p. 71).

> formation of new identities." (Williams, 2003, p. 185) (see also (ibid., pp. 199-200))

It is by sensation that individuals are moved to express certain Ideas that then, from time to time, gain identity by becoming temporally stable. It is also by sensation that actual identities are moved away from their state of stability and moved to express new Ideas. Actual identities are capable of being affected because they are never just themselves (i.e., identities are never absolutely identical). They contain a preindividual component that is reshaped by sensations and drives further individuations. Intensities are key to this description: virtual intensities have their counterparts in actual intensive differences that are already determined within certain domains of manifestation (e.g., physical, biological, psychological, political etc.). The intensive difference is exactly the element in being which according to Simondon makes being fall out of phase with itself. It is the aspect that cannot be equalized, normalized or averaged out and therefore it pushes whatever actual identity out of itself. In other words, intensities manifested in sensation are not themselves representable or recognizable. As such, they are not captured within the image of thought (see discussion in (ibid., pp. 178-185))

> "How is the Idea determined to incarnate itself in differenciated qualities and differenciated extensities? What determines the relations coexisting within the Idea to differenciate themselves in qualities and extensities? The answer lies precisely in the intensive quantities. Intensity is the determinant in the process of actualization. It is intensity which *dramatizes*. It is intensity which is immediately expressed in the basic spatio-temporal dynamisms and determines an 'indistinct' differential relation in the Idea to incarnate itself in a distinct quality and a distinguished extensity." (Deleuze, 1994, p. 245)

We have already mentioned the power aspect of intensity. It is the power expressed as actual intensities that 'dramatizes' the Idea and makes it embodied and sensible. What Deleuze describes here is a difficult operation which is best illustrated using the state-space metaphor of Ideas. The structure of Ideas is analogous to a vector field where each point is assigned with a differential vector that expresses the reciprocally determining relations of state variables (the dimensions of the Idea)[6]. The determination of the 'indistinct' differential relation is achieved as a specific trajectory is selected in the state space and followed. Such a trajectory corresponds directly to the behaviour of a certain actual system or phenomenon. The selection of a trajectory is taking place within a process of individuation.

Deleuze is deploying Simondon's terminology to account for how phenomena arise due to actual intensive differences which themselves are exteriorizations of virtual intensities:

[6]See a more detailed description in chapter 10.

> "How does intensity fulfill this determinant role? [...] The essential process of intensive quantities is individuation. Intensity is individuating, and intensive quantities are individuating factors. Individuals are signal-sign systems. All individuality is intensive, and therefore serial, stepped and communicating, comprising and affirming in itself the difference in intensities by which it is constituted. " (ibid., p. 246)

The nature of signal-sign systems is further explained in the following quote, which complements the previous one describing how actual phenomena finally emerge in a progressive determination of factors that coordinate disparate orders of differences and bring them into communication:

> "Every phenomenon flashes in a signal-sign system. In so far as a system is constituted or bounded by at least two heterogeneous series, two disparate orders capable of entering into communication, we call it a signal. The phenomenon that flashes across this system, bringing about the communication between disparate series, is a sign. [...] Every phenomenon is composite because not only are the two series which bound it heterogeneous but each is itself composed of heterogeneous terms, subtended by heterogeneous series which form so many sub-phenomena. The expression 'difference of intensity' is a tautology. Intensity is the form of difference in so far as this is the reason of the sensible. Every intensity is differential, by itself a difference. [...] We call this state of infinitely doubled difference which resonates to infinity disparity. Disparity - in other words, difference or intensity (difference of intensity) - is the sufficient reason of all phenomena, the condition of that which appears. [...] The reason of the sensible, the condition of that which appears, is not space and time [alluding to Kant's categories] but the Unequal itself, disparateness as it is determined and comprised in difference of intensity, in intensity as difference. " (ibid., pp. 222-223)

Signals are the mediating mechanisms between two disparate orders or series of differences that enter into coupling. These can be illustrated as the establishment of an effective communication channel, or a communication medium. All phenomena are signs (i.e., passive synthesis of intensive differences). Signs are that which is sensible, i.e., given to sensation. From a slightly different perspective, phenomena are given in terms of a distribution of qualities within extensity. Inasmuch that these are given to sensation, both extensity and qualities express intensities. Such expressions, however, are always observed to cancel or equalize the intensities that bring them forth. For example, water flowing down the mountain cancels the difference in potential energy that brings it to move; eating eliminates the intensity apparent in the feeling of hunger that drives the organism to seek for food and feed; people spend the money they have (economic intensity) by buying goods, etc.

> "[T]here would no more be qualitative differences or differences in kind than there would be quantitative differences or differences of degree, if intensity were not capable of constituting the former in qualities and the latter in extensity, even at the risk of appearing to extinguish itself in both." (Deleuze, 1994, p. 239)

> "There is an illusion tied to intensive quantities. This illusion, however, is not intensity itself, but rather the movement by which difference in intensity is cancelled. Nor is it only apparently cancelled. It is really cancelled, but outside itself, in extensity and underneath quality." (ibid., p. 240)

This relation of intensive differences to phenomena is found everywhere. Consider the energy gradient between what planet earth receives in the form of radiation from the sun and what it radiates back to space. This gradient is an actual intensive difference that "drives fluxes of matter and energy" (DeLanda, 2013, p. 60). One obvious example of the complex phenomena that arise is weather systems. But even more complex in terms of its distribution in extensity and qualities is the phenomenon of the biosphere, which is a very complex sign-signal system of systems. All life on the planet can be said to exist and be animated by this gradient while actively cancelling it. In thermodynamic terms lifeforms maintain their organization against entropy by recruiting parts of the energy gradient to perform localized work (e.g., metabolism, reproduction, hunting etc.). On a longer time scale, the whole evolutionary movement of life is a movement of individuating complex Ideas as lifeforms. Specific lifeforms evolve (individuation of species), reach a certain stability and then gradually transform or become extinct. The net energetic gradient is continuously dissipated while bringing forth the whole phenomenon of life (for a more in depth analysis see (England, 2015; Schneider and Kay, 1994)).

There is a kind of an apparent contradiction here. While actual intensive differences tend to cancel by bringing forth phenomena, their virtual counterparts do not change. This reflects an even deeper puzzle: how does the dynamism of phenomena correspond to the static nature of the virtual? The solution to this apparent illusion lies in individuation processes. Whatever is actualized in the biosphere at a given moment is only one instance of expressing virtual Ideas. Life is a vast multiplicity with inexhaustible richness of Ideas that can actualize as specific lifeforms. Every individual organism is actualizing the whole of life but while it expresses certain Ideas clearly (e.g., four legged, mammal, predator,...) other ideas are entirely obscure (e.g expressing a gene shared by most life forms, bacteria, plants, fungi, insects, mammal, etc.). When intensive differences are cancelled, these are only exteriorized differences being cancelled. These affect relations between actual manifestations and the configurations of virtual intensities being individuated. Indeed, on the virtual plane nothing changes, series of intensive differences develop within the static structure of the plane along lines that converge into Ideas or escape them depending on relations with other intensities. Contingent individuating factors determine which lines are selected and which Ideas are distinctly expressed as the infinite plane of Ideas is inexhaustibly explored. Correspondingly, actual intensive differences only change form as they synthesize into varying sensible manifestations.

Deleuze goes as far as distinguishing two kinds of energy. Conventional energy, which is subject to empirical and scientific investigation and where conservation laws hold, and transcendental energy associated with pure intensity and transformation:

> "Energy in general will not then be confused with a uniform energy at rest [i.e., conserved in different manifestations], which would render any transformation impossible. Only a particular form of empirical energy, qualified in extensity, can be at rest; one in which the difference in intensity is already canceled because it is drawn outside itself and distributed among the elements of the system. However, energy in general or intensive quantity is the *spatium* [virtual depth beneath actual reality], the theatre of all metamorphosis or difference in itself which envelops all its degrees in the production of each. In this sense, energy or intensive quantity is a transcendental principle, not a scientific concept. In terms of the distinction between empirical and transcendental principles, an empirical principle is the instance which governs a particular domain [i.e., physical, biological, economic etc]. Every domain is a qualified and extended partial system, governed in such a manner that the difference of intensity which creates it tends to be canceled within it (law of nature). [...] On the other hand there is an intensive space with no other qualification, and within this space a pure energy. The transcendental principle does not govern any domain but gives the domain to be governed to a given empirical principle; it accounts for the subjection of a domain to a principle." (Deleuze, 1994, pp. 240-241)

In this quote, Deleuze draws the connecting lines between the empirical philosophical method also adopted by science and his transcendental system. The universe reflected by Deleuzian philosophy is open-ended and is not bound by the phenomenal world or the known laws of nature. Such a universe extends beyond the phenomenal in that it embraces the unknown (or the determinable as that which is not yet known) as well as the known (the determined in individuals or complete determinations of laws). Notice that virtual differences and the transformations they spell are never exhausted because they are not active and do not cause anything. The cancellation of intensities in the actual dimension is only within a certain domain of manifestation that always assumes certain invariants that characterize the domain. Philosophically speaking there is no reason to assume that the whole universe is placed under such invariants. The ultimate open-endedness and the virtuality of difference need not presume a universal principle of entropy.

5.3 Metaphysical Self-organization Revisited

In 3.4.4 we forwarded the hypothesis of metaphysical self-organization based on Bergson's metaphysical schema. From a meta-philosophical perspective, such a hypothesis is inevitable. As long as an identity-based metaphysical schema is considered, it automatically accounts for being – for what *is* by means of a metaphysical element, be it a material atom, substance, a transcendent Idea or something else. But when ontogenetic schemata, such as the ones developed by Bergson, Simondon and Deleuze, are considered, they do not automatically account for the existence of order and stable entities as these are only products or effects of process. It is not only the case that all concrete objects, systemic organizations and states of affairs are secondary products, in a mobile reality all such products are impermanent and bound to change as the processes that produce them never cease. This of course begs the question of how order and permanence, i.e., a relative notion of these, are accounted for; why is there order rather than just disorder? The hypothesis of metaphysical self-organization comes to answer this question. Given the mobile metaphysical foundation of reality it can be put as follows:

$$Chaos(Disorder) \rightarrow Organization \rightarrow Chaos(Disorder) \tag{5.1}$$

where chaos or disorder stands for a foundational indifferent reality from which everything emerges and to which everything returns. The term self-organization requires clarification: it cannot be said that organization has its own sufficient reason. It rather finds its reason in the fundamental mobile reality it presupposes. Self-organization therefore is the feature of the chaos (or indifference) that precedes organization and not of organization itself. In its metaphysical sense, self-organization comes only to clarify that there is no element or principle transcendent to reality that imposes organization (e.g., a godly principle). It is reality that organizes, in itself and for itself.

In Bergson's schema, it is the heterogeneity of undivided reality (i.e., where any division only means a change in nature) that supports the emergence of relatively stable structures. For Simondon existence is both being and becoming and its metastability accounts for intermittently stable identities. But Deleuze's schema is perhaps the clearest: the formula of determinability, reciprocal determination and complete determination (i.e., concrete instantiations of states of affairs), claims indifference to be determinable and how differences as events of unilateral determination bring forth structure that is then expressed in actual, more or less stable, organizations. But difference alone would not possibly be a sufficient reason for organization if it was not the case that difference repeats. Repetition and orders of repetition along with difference are instrumental for organization and the emergence of identities.

Ideas as multiplicities bring forth in their individuation a multiplicity of unique individuals. The internal repetition in the Idea (its multiple nature) is expressed in the external repetition of individuals and forms populations of individuals (see

8.1 ahead). This is best exemplified in organisms that belong to a species (which is itself an individual). Only on the basis of this external repetition, can recurrent patterns, habits, similarities, invariants, generalities and all other signifiers of order be derived[7].

An additional important aspect of individuated order is to do with symmetry breaking. The structure of the virtual described in chapter 4 is ingenious in that it describes fundamental reality as both different and indifferent. It begins with unilateral determinations, where the indeterminate always endures in the determined, and continues with the fundamental equivalence and univocity of all Ideas. The virtual is no less disordered than ordered. Only the individuation of the virtual brings forth distinct patterns of order because fundamentally it is a symmetry breaking event. It expresses only certain specific Ideas while obscuring others. This is how ordered existence appears even if every particular instance of such existence is but a fleeting instance, flickering in and out of actuality[8]. And this is why individuation is ultimately creative. It is however simultaneously and inseparably both creative and destructive as expressed by the formula above.

As already hinted, self-organization in the metaphysical sense is responsible for space, time, all the sensible qualities and of course natural laws. Natural laws seem to express many actual invariants considered to be universal. But even these cannot be proved to be absolutes. A case in point is a progressive theory in fundamental physics (Smolin, 2013) that challenges the invariance of the laws of physics and hypothesize an evolutionary process of natural laws. From the perspective presented here, the physical universe is a configuration of reciprocally determined variables and these determinations may indeed be expressed as actual invariants without contradicting the transcendental principle discussed in 5.2.2.

Metaphysical self-organization does not itself produce anything. It is only the hypothesis that inasmuch as organizations actually exist, they are always products of a creative process. As such, organization cannot and does not presuppose a prior organization or principle. Organization individuates and individuation is understood in terms discussed throughout this chapter. Organization appears, disappears and reappears as illustrated in the above formula, but it never reappears the same or identical, only as different. This is Deleuze's creative interpretation of Nietzsche's concept of eternal return:

> "When we say that the eternal return is not the return of the Same, or of the Similar or the Equal, we mean that it does not presuppose any identity. On the contrary, it is said of a world without identity, without resemblance or equality. It is said of a world the very ground of

[7] In object-oriented metaphysics these signifiers are inherent in the element of identity.

[8] An instance is an indefinite period of time be it as brief as the lifespan of an elementary particle or as long as the lifespan of a universe. In a mobile reality everything is only relatively enduring.

which is difference, in which everything rests upon disparities, upon differences of differences which reverberate to infinity (the world of intensity)." (Deleuze, 1994, p. 241)

It is beyond the scope of this work to explore the concept in depth, but its importance lies in emphasising the contrast to how self-organization is conventionally understood, that is, attractors as self-identical states in the development of a system's dynamics, and the reduction of a system's degrees of freedom in the course of self-organization. Instead, self-organization, as the ontogenetic process it is, and as a process of progressive determination, is not necessarily characterized by movement towards stability, invariance and identity. Such movements are merely passing phases.

When Deleuze writes that everything rests upon disparities, we are reminded of the signal-sign systems that individuate in order to bring into communication disparate orders. As such, communication does not presuppose any prior principle or knowledge. It is fundamentally experimental and its success is serendipitous. In this very sense, organization is created rather than discovered, much in the same way as how life's creativity is expressed in evolution.

5.4 Concluding Notes on Deleuze's metaphysics

5.4.1 Every Thing Thinks

The idea developed from Bergson through Simondon and Deleuze and in at least some sense began in the teaching of the Buddha about unsupported thought, is one that far exceeds the universe of representation as reflected in the image of thought. It is not only a philosophy that puts us in touch with the origins of thought but teaches of thinking beyond the human condition, or put otherwise, frees thinking from the particular thinkers humans are. Furthermore, it frees thinking itself from any method or image by showing how the unthinkable brings forth thought in the "fundamental encounter" Deleuze writes about. We must not forget that the image of thought itself individuates. Once it is brought in touch with that which precedes it, it is already transformed.

The perspective developed in this thesis, the bottom line of this philosophy that brings thought to its metaphysical mobile element is most elegantly expressed in the following:

> "*Every body, every thing, thinks and is a thought to the extent that, reduced to its intensive reasons, it expresses an Idea the actualization of which it determines* [my italics]. However, the thinker himself makes his individual differences from all manner of things: it is in this sense that he is laden with stones and diamonds, plants 'and even animals' [i.e., all the Ideas it connects to but are obscured in the immediate expression]. The thinker,

> undoubtedly the thinker of eternal return, is the individual, the universal individual." (ibid., p. 254)

The universal individual – the thinker of eternal return, is of course the interconnected multiplicity of all that exists. Ironically one can surely read in this a reflection on the "I think therefore I am" to which this whole philosophy stands as criticism. It is only in Deleuzian metaphysics that being and thinking come to significantly coincide in all things. Faithful to his own method, Deleuze demonstrates a critique that does not negate but rather transforms, repeats (with a difference) and in that affirms.

5.4.2 The event of cognition

Conventionally, cognition is a broad concept describing activities of acquiring and processing knowledge for the purpose of acting. It is almost counter intuitive to think of humble objects or physical processes as endowed with cognitive capabilities and even less to consider them as thinking entities. Following the notion that thinking is a foundational formative process driven by intensities, the meaning of cognition is transformed too. First, cognition, as opposed to re-cognition that already implies thought within its image, is not an event of discovery but one of creation. The unknown does not become known via a process of discovery, the unknown is a creative field of difference (the "stones and diamonds, plants and even animals" do exist but only as a confused and enmeshed fabric of multiplicities) and the known is born out of it. This is not to be confused with the position of radical constructivism which is basically a solipsist position. Cognition is all about encountering the sensible (intensive differences) and making (individuating) an actual sense that brings forth an actual concrete expression of Ideas. As will be shown in the following chapters, the event of cognition is to do with boundary formation, where thinking transitorily "falls into actual identity".

On the surface, the event of cognition is the event where actual things affect and are affected by each other. Via interaction – a repetitive exchange of signs – they mutually maintain their respective identities (see chapter 9 ahead). The event of cognition is an individuation that has reached a stable regime – a resolution of a problematic situation, where disparate orders establish communication. The exchange of signals-signs is how things appear for each other or in other words, make sense to each other. Such an exchange involves a notion of information inseparable from significance. The whole process within the event is experimental and has an intrinsic serendipitous aspect. We are mostly oblivious to this formative process because our well established image of cognition focuses on stable products and not on the productive processes underlying them.

Thought and cognition in the very broad sense presented here are almost synonymous and interchangeable. Thought extends far beyond what we conventionally consider mental activity taking place in brains. Cognition does not involve specific sensory faculties, only interaction and affect (the sensible). There is the question of how in this transformed terminology cognition and thought are related, and a second question regarding how the event of cognition relates (if at all) to contemporary theories of cognition. There are subtleties of description and significance that nevertheless differentiate thought and cognition and may prove useful when coming to reflect on concrete discipline-bound theories and models in the light of this metaphysical schema. The differentiation of thought and cognition is itself an individuation that depends on the complexity of the systems being individuated. Simondon categorically identifies in his work more or less distinct regimes of individuation and the nature of individuals belonging to each regime (see 5.1.3). Following Simondon's method (but not necessarily its particular application), we propose a concept of complexity based on the proportion between relations of exteriority and relations of interiority, which is required for describing a system in a certain context.

Simple systems can be said to be characterizable by their present relations of exteriority and have very little if any relevant interiority. Complex systems, having a relevant depth, require to address their relations of interiority too (which immediately makes them more difficult to observe since relations of interiority can only be inferred). Simple systems are more readily reducible to concrete components and relations, while complex ones, being productive and sensitive to their enduring past, are hardly so. In Deleuzian terminology, simple systems express a highly distinct but very limited range of Ideas, while all the rest is well obscured. Complex systems, in contrast, express a wide range of Ideas albeit each much less distinct in expression. The individuation of complex systems rarely settles on very stable and distinct behaviours, while that of a simple system does.

This is a rough distinction but it is useful for our immediate purpose. For simple systems, there is little if any reason to differentiate cognition from thought. Having little depth, such systems are more of the 'what you see is what you get' kinds of system. They undergo individuation but the range of Ideas they actually express is pretty much limited, which allows the inference of distinct inner states. Complex systems, having depth of interiority, are harder to characterize based on a limited sample of interactions. They undergo inner transformations that may change entirely their actual expression in the course of such changes. It is only for such systems that it makes sense to differentiate cognition from thought, that is, to separate the regime of more or less immediate interactions from another, interior and only implicit regime of ongoing transformation. When we represent a system we exteriorize it and by applying symbolic representation to its interiority it becomes simultaneously more simplified and accessible and less realistic. Representation turns thought from productive to cognizable and from nomadic to sedentary. Notably, it might be a matter of a single interaction with an additional element that may turn a simple system into a complex one and vice versa.

In summary, from a metaphysical perspective, the differentiation between thought and cognition carries no consequence and is therefore context dependent. Yet, this differentiation can become significant once it reflects the complexity of the individuation process itself, in other words, it is itself already an actual expression.

5.4.3 Influence on Human Thought

The exposition of these philosophical ideas will remain incomplete if their influence on human thinking is not briefly addressed. Williams (2003, p. 1) writes:

> "The innovation [in Deleuze's work] is as much about how to live and how to create as it is about a philosophical view of the world. "

Towards the conclusion of his book he adds:

> "That opening of thought can only take place through experimentation and through moves beyond the boundaries of what is known or deemed proper to a given faculty, since to remain within such limits is to remain with actual identities and to strengthen the illusion that thought takes place through identification as opposed to transformation." (ibid., p. 196)

Creativity and experimentation is an integral aspect of thinking and thinking for Deleuze is nothing other than living. New thoughts connect via the intensities carried by sensation, and learning is achieved in the interpenetration of Ideas, as reflected in the following:

> "The movement of the swimmer does not resemble that of the wave, in particular, the movements of the swimming instructor which we reproduce on the sand bear no relation to the movements of the wave, which we learn to deal with only by grasping the former in practice as signs. [. . .] We learn nothing from those who say: 'Do as I do' [repeat the same]. Our only teachers are those who tell us to 'do with me' [repeat with difference], and are able to emit signs to be developed in heterogeneity rather than propose gestures for us to reproduce. In other words, there is no ideo-motivity, only sensory-motivity. When a body combines some of its own distinctive points [singularities] with those of a wave, it espouses the principle of a repetition which is no longer that of the Same, but involves the Other - involves difference, from one wave and one gesture to another, and carries that difference through the repetitive space thereby constituted. To learn is indeed to constitute this space of an encounter with signs, in which the distinctive points renew themselves in each other, and repetition takes shape while disguising itself. " (Deleuze, 1994, p. 23)

Deleuze's metaphysics is definitely revolutionary with the nature of its break from a dogmatic object-oriented way of thinking and behaving, one that is biased towards identity and stability. It is not about merely replacing object metaphysics with process metaphysics, a feat already accomplished before him. The significance of Deleuze's metaphysics is that it is ultimately open-ended. It is open-ended because it exposes the abyss at the edge of the known and embraces it instead of constructing walls and safety nets. It invites the thinker to go there and create, undoing herself in the process (see (Deleuze and Guattari, 1987, chap. 6) for a provocative meditation on the topic).

There are quite a few values that can be inferred from this philosophy in response to the question of how to live. Openness, connectivity, affirming the Other and acceptance of change are perhaps the prominent ones. Yet, above all I find in this philosophy support to a foundational direction proposed already in the introduction: that living is intrinsically significant only in the light of the possibility of evolution.

Chapter 6

From Difference to Thought

This chapter is a summary and reflection on the metaphysical roots of thought. A major criticism of the work presented in the preceding chapters, which can be equally addressed to any investigation of a metaphysical nature, is that it is speculative and offers no way of validation. Such criticism indeed makes sense under the assumption that a hypothesis is only significant if it can be assigned a truth value or it can be argued to have some plausibility of being true. But truth is hardly the point here. The significance of a metaphysical hypothesis or speculation derives from how it may reflect on and possibly influence the nature and manner by which one comes to know reality. Put differently, metaphysical theory as a system of axiomatic assumptions and beliefs that shapes one's experiences and guides one's thinking processes has a profound impact on the manner one interacts with one's environment and fellow beings. As long as a metaphysical theory is reasonably coherent and consistent (Thagard, 2002) (otherwise it will anyway prove to be unworthy), its value corresponds not so much to its truth but rather to the extent it may allow one to think about reality in novel ways and the horizons of experience and knowledge it opens.

My core belief and premise is that as living, cognitive, thinking entities, our encounter with reality is fundamentally experimental. As living organisms we are products of an evolutionary experiment; as cognitive agents, our actions derive from life-long experience and a lot of trial and error; as thinking entities we experiment with ideas, models, theories and stories in order to make sense of reality, understand and manipulate it. In this very sense, philosophy, and metaphysics in particular, is an experiment in thinking that goes far beyond the pursuit of truth in the narrow sense of logical evaluation or empirical fact checking. Furthermore, in the theory presented here the very notion of truth undergoes individuation. Understanding truth as something that exists *a priori* to its discovery is rooted only in identity based metaphysics.

The metaphysics proposed here is a work in progress and is meant to remain so. It need not even display the strict coherency and consistency that we would expect from fully individuated theories. Even in physics, where so much effort and ingenuity are invested, the two major theories, general relativity and quantum theory, each highly successful on its own terms, are not entirely coherent with each other and their disparity is nowhere close to resolution. The experimental nature of the theory presented here need not play against it. It need only make enough sense (i.e., to be disturbing enough) as to introduce a minute shift – a difference from that which is obvious and given in conventional thinking.

As to a more concrete motivation, we live in an age when we are on the verge of building competent cognitive systems and powerful thinking machines that may sooner or later exceed human capabilities and shortly after even the human capability to understand them. We live in an age when we have achieved unprecedented levels of organizational coordination and collaboration to the extent of witnessing the emergence of large scale cognitive organizations capable of autonomously sensing their environment, making sense of it and pursuing their own values and goals accordingly. In such an age it is high time to explore the ways we understand thinking, its conditions, its limitations and its evolutionary potentials. A primary goal of this thesis is to make the case that the metaphysical speculation presented here is indeed significant for how humans may understand themselves, the complex reality they are part of, which is at least partially of their own making, and the possible horizons of a future evolution beyond the human condition.

The key to understanding the terminology used here to reflect on thought is to relate to it as a multiplicity. There is no single definition but rather multiple, partly overlapping, co-defining terms, each highlighting and emphasizing particular aspects in relation to the others. Individuation, ontogenesis, metaphysical self-organization and the event of cognition are all facets of thought. Individuation is used to describe thought as the process linking the actual and virtual aspects of reality. Individuation is the most significant and encompassing facet of thought. Two technical terms associated with individuation are progressive determination and transduction, as explained in chapters 4 and 5. Metaphysical self-organization plays a double role: first it describes thought as the formative process that brings forth order from disorder. Second, it provides a metaphysical ground to all the concrete manifestations of self-organization. Cognition and thought in their metaphysical sense are used interchangeably. All cognitive activities are forms of thinking, and thinking as individuation – the bringing forth of sensible individuals – is cognitive activity. Thought and cognition are nevertheless differentiated depending on the more specific context in which they are applied, as explained in chapter 5. The term 'event of cognition' highlights the sense-making aspects of individuation, boundary formation and affect. The event signifies an actual significant appearance of a boundary, of a fully individuated distinction or relation, and of an identity that persists. Additionally, this term will be used in the second part of the thesis to anchor the enactive cognitive theory to the metaphysical schema developed here. Last but not least, the term ontogenesis is used to highlight the creative aspect of individuation and the inherency of becoming in being in contrast to the givenness of being.

Following are the major points of the philosophical framework developed in this part.

6.1 Thinking beyond Representation and Image

There is no point in recounting the obvious advantages of representation and object-oriented thinking. Even the writing of this thesis and the research it is based on would not have been possible without symbolic representations that are, as Bergson remarked, foundational to language and reasoning. Yet, as shown in the preceding chapters, representation and object-oriented thinking are limited by exactly the same features that make them powerful. They hide and methodologically neglect the underlying ontogenetic processes that give rise to representations. By that they are capable of bringing forth an image of reality in terms of clear and distinct objects and relations and a powerful toolkit for manipulating these objects and relations. Thought as the manipulation of representations, however, is ultimately limited. This limitation is far from being apparent, if only because the space of thought supported by representation is vast and inexhaustible. In a quite famous poem Emily Dickinson wrote:

> The Brain–is wider than the Sky–
> For–put them side by side–
> The one the other will contain
> With ease and you beside–

However vast conceptual spaces are, the space beyond representation and image is yet immeasurably vaster. Whatever can be conceptualized, symbolized, or represented occupies a space which is outright negligible in comparison to the space beyond representation. But what does it mean to go beyond the image of thought into a realm that can only be described as thought sans image? Isn't the very attempt paradoxical? Indeed as already presented in chapter 2, thought without image – unsupported thought – goes beyond the dogmatic, beyond 'doxa' – the conventional nature of thinking. Commonly a paradox is synonymous with logical impossibility or inconsistency. But paradox in the sense meant here is not to be confused with either. It is rather the state of affairs that comes prior to logical predicates, propositions and concepts. It is the realm where sense itself is formed but is not fully individuated as yet. This is not the kind of paradox that requires resolution. It invites a leap of insight that expands thought beyond its own prescription.

Access to the realm beyond representation is gained by replacing identity with difference as the element of thought. This replacement prompts (among other things) the elimination of the sharp distinction between the known and unknown (as alluded by metaphors such as light and darkness). Knowing is determination, is difference; inasmuch as the known distinguishes itself from the unknown via progressive determinations, the unknown does not distinguish itself from the known and adheres to it. Whatever can be known is never known once and for all. No determination is a final and complete determination. Instead of the illusory sharpness of distinction between the light of knowledge and the darkness of the unknown, there is a metaphysical continuum of ongoing individuation that can only be palpated.

Wherever there is a difference and in as far as this difference is affected by or affecting other differences, there is the beginning (and the continuation) of a new thought well before anything can be represented and throughout the realm of representation as well. Once the unknown is not neatly boxed into error margins and bounded uncertainty or is simply excluded and entirely disregarded from one's reality, thinking necessarily becomes creative, open-ended, complex and all-encompassing.

Thought as individuation does not develop uniformly from a disordered formlessness into fully determined ordered systems. Actual expressions always combine aspects that are highly determined with aspects that are not yet determined or in the course of determination. Thought as individuation is not a unidirectional process either, only moving from indetermination to determination and from disorder to order. In the sense suggested here, thought is also forgetfulness, disintegration and dissolution of distinctions (destructive thoughts). Actual forms appear and disappear as certain Ideas become clearly expressed while others become confused and obscure.

The image of thought and object-oriented thinking discussed in chapter 2 are already products of complex individuations and reflexive relations arising in them, i.e., when individuation is complex enough to involve self-reference. In this sense, object-oriented thinking is already thinking within thinking – a special case where a thinking agent, objects of thinking and the relation between them are all distinctly individuated and form among them stable relations. But the apparent identity of represented objects is illusory. Object-oriented thinking hides the underlying formative processes of thinking as individuation as it tends to keep its objects as stable unchanging identities (i.e., subjugating all difference to identity). Every concept, every object, every relation and every thinker is inherently metastable and contains a preindividual aspect that can always drive further individuation and transformation.

It cannot be overemphasized that the proposition of thinking beyond the image of thought does not come to devalue or negate representation-based thinking. It only exposes the ground that brings forth thinkers and everything thinkable in the course of its inherent and inexhaustible process of metaphysical self-organization. There is something both liberating and terrifying in the realization that the thinkers that we are and what is possibly thinkable to us, are not given. There are always other individuations – lines of flight and escape routes from the conditions that define us and the way we think. These are not there awaiting discovery; they are becomings, unformed opportunities in the gaps between what is apparently given at every moment.

6.2 The Ontogenetic Nature of Thought

The most significant outcome of moving beyond the image of thought is realizing the necessity of an ontogenetic process taking place just on the borderline between the unknown and the known. After considerable study and reflection I did not find a basis – a valid ontological element that comes before thought and can lend support to thought in the most profound sense of the word. Thought, it seems, must itself reach to the unthinkable and tap it directly without mediation. There can be no prior ground to thought other than the unthinkable – that which lies beyond thought. Forcing the unthinkable into being a thought is indeed an act of metaphysical violence – an act of creation and birth.

Thought as ontogenesis replaces *a priori* given metaphysical elements. This is not merely a conceptual shift from object-based to process-based metaphysical perspectives. Ontogenesis – becoming, or the coming into being of the sensible (and knowable) is not given to closed formal definitions and formulations. It exceeds conceptual thinking per se and taps into realms where no single method or framework can be applied. Thought as ontogenesis is therefore a problematic proposition inherently experimental and as such cannot be expected to consolidate and become a mainstream theory (see quote on page 31). It will always remain on the fringe of whatever mainstream it might bring forth. In other words, thought is self-producing but since it is unsupported by any *a priori* organizing principle, there is no way that its self-production can be predicted, inferred or placed within a structured framework. It is this feature (or rather lack of) that makes thought as the becoming of being open-ended in the deepest sense[1].

Thought as ontogenesis highlights the creative aspect of individuation and the baseless nature of such a creation, the absence of a metaphysical "*a priori*". But this absence of a primal element must not be understood as nothingness or an ultimate negation. The absence of a primal element is rather an ultimate *affirmation* of all and everything at once, of the ultimate plenum, where no single body can be distinguished. Ontogenesis proceeds in determinations where each such determination is a symmetry-breaking event as differences arise from indifference. Symmetry is normally considered as belonging to the order of things, to harmony and beauty. The breaking of symmetry can therefore easily be confused with the opposites of these. Symmetry, however, is synonymous with indifference and invariance and as Deleuze notes: "The reason of the sensible, the condition of that which appears is not space and time [as invariant indifferent medium] but the Unequal in itself [...]" (Deleuze, 1994, pp. 222-223). Symmetry breaking in this sense is to be understood as the breaking of indifference which allows actual expressions to appear. As already mentioned, the movement of thought is always converging towards certain Ideas while diverging away from other Ideas. Individuals always manifest certain Ideas clearly while all others remain obscure. This is the fundamental asymmetry of existence – not everything goes at once. If all Ideas were to be equally expressed, there would be no actual distinctions and no sense would have been possible.

In more concrete terms, the ontogenetic nature of thought is most apparently expressed in three major categories of processes: *a*) processes of self-organization,

[1] Bergson's argument for freedom is based on a similar observation. See (Bergson, 2001, chap. 3-4).

b) evolutionary processes, and *c*) cognitive processes or, more accurately, processes of cognitive development. Based on the metaphysics of thought developed here, these processes can be considered as specific forms of thinking that are described within specific conceptual frameworks. Invariably such processes involve elements of contingency and random influences that introduce unpredictable turning points of convergence and divergence (e.g., an unpredictable coupling between components that causes unexpected resonance in mechanical or electronic systems, a pandemic that disrupts the delicate balance of populations within an ecosystem and causes events of speciation, an unexpected experience like falling in love that changes a person's worldview and way of life, a rumour that crashes the stock market etc.). It is due to such serendipitous events that no general formulations or models can be worked out for ontogenetic processes[2]. These express the intimate role of the unknown in shaping the actual present and its significance.

Another critical aspect in the manifestation of ontogenetic processes is reflexivity and feedback (see chapter 9) among its differential elements (e.g., A affects B, which affects C, which affects A, etc.) that correspond to the reciprocal determination existing among variables that constitute virtual Ideas. The genesis of individuated metastable entities (identities) must depend on convergent reciprocal determinations. Convergent here means reflexive relations between differential elements that progressively constrain the expressions of Ideas into more or less repeating patterns of identifiable actual behaviour. For example, the appearance of attractors and strange attractors in the behaviour of dynamic systems. More generally, repetition is how ontogenesis brings forth individuated identities, and conceptually every identity is an attractor – an instance of constrained development of differences. Reflexivity is indeed the aspect of ontogenesis that ensures that metaphysical self-organization can converge to metastable order but is fundamentally short of predicting, inferring or otherwise determining (without further assumptions or knowledge about prior individuations) what kind of order may arise or why this order may have arisen rather than another. There is an indefinite number of ways for the universe to organize, be known and reasoned about, just as there is an indefinite number of ways for thought to unfold and manifest.

6.3 The Universality of Thought

In his words "Every body, and every thing, thinks and is a thought...", Deleuze proclaims the universality of thought and its extension beyond the human as well as beyond anything organic. Thinking as individuation is the fundamental process of bringing forth order in all its forms and modalities. Thinking spans as a continuum from the most elementary reciprocal determinations that constitute simple natural

[2]It is due to the extreme sensitivity of ontogenetic processes to perturbations that eggs and wombs have evolved to provide a relatively isolated and regulated space for the complex developmental processes of life to take place.

patterns (e.g., photons as the reciprocal determination of electric and magnetic differences) to the most complex individuations such as the ones taking place in brains, among brains, and other highly complex systems. Difference, though being the element of thought, does not itself amount to thinking. But as soon as series of differences are related and reciprocally determine each other, they already constitute a virtual Idea that can individuate and become actual in form. Thinking as individuation is a universal process of expressing virtual Ideas where expression is necessarily sensible. Importantly, this proposition falls short of automatically assigning significance to thought. Significance is never universal but rather sensitive to context and contingency. Significance goes beyond the mere expression of form and affect as it is derived from distinctive points and singularities along the unfoldment of difference (see 4.2.3.3). The vast majority of thoughts carry little significance. They bring forth expressions that are regular and non-distinct in their milieus. Be it a grain of sand on a dune or the humble members of society, most individuals leave little or no impact on individuations in which they partake. Still, they think and are being thought and under unique circumstances, they may become critically significant in subsequent individuations, as the old English rhyme goes: "For want of a nail the shoe was lost. For want of a shoe the horse was lost. For want of a horse the rider was lost. For want of a rider the battle was lost. For want of a battle the kingdom was lost. And all for the want of a horseshoe nail..."

Generally, the thinking of bodies is far from reaching the level of symbolic representation. The only individuated product such thinking brings forth is of an *image of a body in itself but only for bodies other than itself*. Such an image is the distinctive boundary of a body in relation to its milieu of all other bodies[3]. It is how it affects things other than itself and how things other than itself affect it. In other words, reciprocal affect is how things make sense to each other. The only image of a body is its actual extensity and interactions (i.e., behaviour) – the way it appears to (or interacts with) other bodies. Descartes's 'Cogito' gains here a novel universal interpretation: the thinking of bodies is what brings them forth as actual distinct entities. There is neither duality of spirit and matter nor of subject and object in this so to speak refurbished 'Cogito'. Thinking ('I think') is immanent to being ('I am') and constitutes its transcendental sufficient reason. Idea and being, the virtual and actual, are the inseparable interior and exterior facets of one reality brought together in thinking as individuation.

Two additional aspects of the universality of thought are universal interconnectivity and universal reflectivity. As already discussed in the preceding chapters, all virtual Ideas form a vast interconnected multiplicity. Actual things and bodies may appear as distinct and separate at certain actual instances while appearing as inseparable at other instances. Actual appearances depend on which Ideas are clearly expressed at any instance and which are obscured and enveloped by other Ideas. It

[3] For an earlier version of the idea see (Bergson, 1991, chap. 1).

would therefore be correct to say that every individual expresses all Ideas but to different degrees of clarity and obscurity, or in other words, that thought contracts the whole of Ideas into each and every individual expression. Not only is every body connected to all bodies but also every body *reflects* all bodies in more or less clarity. It is the movement of thought from one individual to another that draws the lines of distinction. Thought as individuation also means that no body thinks alone and only for itself. Thinking is inherently collective and distributed, lines of separation are mobile and fleeting and so are the identities they delineate (see chapter 8 ahead).

One can hardly refrain from implying a notion of panpsychism from such metaphysical proposition. This implication must, however, be taken with much care as to its meaning. The universality of thought is not to be understood as implying any kind of universal consciousness, sentience, or any other more or less mysterious psychic content. Thought as individuation comes to account primarily for the metaphysical roots of thought that precede representation, conceptualization and by extension any kind of *a priori* organizing principle. As far as this metaphysical investigation goes, the introduction of self-organization as a metaphysical process can be said to cover quite well the questions motivating it. So why is such metaphysical process referred to as 'thinking'? What merit can be expected, if at all, from such a reference, which may seem no more than poetic license? And if there is such merit, does it justify the risks of misinterpretation and misrepresentation allowed by its apparent ambiguity?

There is no clear cut answer to these questions. Conventionally, thinking is a story we tell about certain activities happening in our brains that produce a very wide range of complex phenomena (not the least of which are the sense of self and conscious experience). Though many if not the majority of such activities are far from being well understood, it is a good story in the sense that it helps us to make sense of ourselves and our interactions in the world. It frames, highlights and explains certain aspects of our behaviour and in so doing is helpful in guiding our individual actions. We have an image of thought because it is helpful to have one. It is not that just any image is helpful, it is the image that we have which we find particularly helpful. But nowhere it is given or proved that the image that we have is the most helpful one. Even the criterion according to which we find the image of thought helpful is not a given. It might well be that the way we think about thinking is just an accident, an elaborate contingency in our evolutionary path which was not bad enough to render the thinkers that we are non-viable.

Here we experiment with a novel concept of thinking much less organized and constrained but much more profound. The merit it can deliver is to do with highlighting the open-ended nature and ubiquity of thinking. For example, if every thing thinks and is a thought, as described in the preceding chapters, we need to learn how to think *together with* things rather than just thinking *about* things. This alone may spell a transformative change in the way we interact in the world. Another example is the Copernican shift from identity to difference as the primary metaphysical element and consequently the shift from unity to multiplicity. Identities as primary elements stand as separate equivocal beings, i.e., each having its own singular sense of being, which is basically incommunicable as such. There seems to be something inherently alienating in identity-based metaphysics, something that separates before it can connect. Difference as a primary element implies interconnectedness and univocity of being (every body *is*, in the same sense as every other body). It means that if there is even a single individual that thinks, that is, expressing the Idea of thinking (in whatever sense), then every thing and every body partakes in this very Idea to a greater or lesser extent. Moreover, otherness (difference) is affirming rather than negating as every thing reflects everything else, only differently. Yet, with this said, it is the burden of this thesis to demonstrate further that not only does this metaphysical speculation make sense but it has its own important merits in providing a novel perspective and narrative on thought and intelligence.

6.4 Complexity Thinking

With the metaphysical schema presented in this part and especially the argument for metaphysical self-organization, complexity theory and complexity thinking receive a proper metaphysical ground (Protevi, 2006). Proper in the sense that it needs no longer rely on reductionist approaches such as the Newtonian deterministic worldview or the Aristotelian hylomorphic theory that posits form as transcendent to matter. The virtual aspect of reality is inherently complex in a manner that cannot be modelled or systematized. The actual aspect, in comparison, being a product of individuation, is simple. Distinct identities, relations and processes – whatever can be symbolically represented or modelled – may appear complex but this is a comprehensible and describable complexity. These individuated entities hide beneath them a complexity of a more profound kind. Only when this profound complexity rises to the surface of actuality and manifests its not yet fully individuated nakedness of pure intensities, is it possible to experience something of its untamed nature in the form of certain chaotic phenomena (see examples in chapter 10). But even then the complexity of the virtual can only be inferred as it remains beyond the reach of direct empirical observation, which by definition is confined to actual phenomena. It is indeed widely accepted that the observable universe is highly complex yet the idea guiding the thinking about the complex universe is that simple elements, relations and laws underlie all complex phenomena and can be discovered. In other words, this idea reflects a belief that the universe is, at least in principle, comprehensible. In contrast, the metaphysical schema presented here reflects a universe which is fundamentally incomprehensible and where comprehension is the exception.

This incomprehensibility, however, has nothing to do with the limitations of human intelligence or for that matter of any intelligence whatsoever. It rather means, paraphrasing Spinoza's words: "we do not know what the body can do", that the creative process of thought as individuation by which the universe becomes sensible and comprehensible is inexhaustible. There is therefore no hope in searching for an overarching 'theory of everything' after which what will remain is just working out the 'details'. The universe, being fundamentally complex, can only be understood in complex terms, multiple concepts, approaches, and theories all of which are experimental and never complete or final[4].

The prospect of developing complexity thinking as an independent paradigm must accept and experiment with thought beyond image and thereby beyond what is given to conventional reductionist reasoning and empirical observation (especially the over importance assigned to strict definitions) that are the cornerstones of dogmatic scientific investigation. Complexity thinking, however, does not come to criticize the scientific method or replace it. It only aims to address the kinds of phenomenon where scientific methods fall short. Concepts such as difference, multiplicities, singularities, metastability, individuation, mobility and duration contribute rich conceptual tools to complexity thinking and the investigation of complex phenomena. Once complex systems are understood as systems of individuation, the dogmatic need to frame everything in terms of stable identities, relations or systems is relaxed. The non repeatability and the lack of general overarching laws are no longer conceived as threatening and can be addressed, albeit with different tools and methods that must themselves individuate along. This is perhaps the most significant difference between thinking *about* phenomena and thinking *with* phenomena. Beyond representation thought is connection and interaction, an ongoing exchange of intensities and signals. No separation is possible between thought, its subject and its objects. Such separation, when it becomes apparent, is already a consolidated product of individuation.

Thinking the complex goes beyond the concept of system as it is conventionally used in the term 'complex system' (more on this in part two). From the perspective of dynamics, a system is already a product of an individuation process. A system arises as its contour consolidates, but this contour is never entirely stable and new interactions of the system with its environment can radically transform it or bring about its disintegration[5]. The organization which identifies a system is a metastable product of its individuating interactions. Deleuze and Guattari (1987) develop two concepts to designate a new kind of "system beyond system" or a *parasystem*. The first concept is *Rhizome* (chapter one). A rhizome signifies a complex a-systemic and heterogeneous structure where each and every location can and should be a connection point leading both inside and outside the structure and each line both connects

[4]An interesting derivation of this conclusion in terms of computation known as *the principle of computational equivalence* was developed in (Wolfram, 2002). Briefly, it claims that all phenomena that can be given simple condensed descriptions are actually a rare exception rather than the rule. The description of the vast majority of phenomena will always require infinite computation because they never reach a final stable individuation.

[5]See for example Maturana and Varela's treatment of structural drift (Maturana and Varela, 1987). This will be further discussed in the second part.

and breaks (many connections across a defining boundary break the boundary eventually). The concept is drawn from its etymological meaning, where 'rhizo' means combining form and the biological term 'rhizome' describes a form of plant that can extend itself through its underground horizontal tuber-like root system and develop new plants. In contrast to the concept of system, the rhizome does away with both *a priori* defined inputs and outputs and an *a priori* internal division to components and their relations. In a rhizome there is much going on underground in connections and interactions that are neither part of the formal definitions and contours of the conventional system nor of its defined interactions.

> "Let us summarize the principal characteristics of a rhizome: unlike trees or their roots, the rhizome connects any point to any other point, and its traits are not necessarily linked to traits of the same nature; it brings into play very different regimes of signs, and even nonsign states. [...] It is composed not of units but of dimensions, or rather directions in motion. It has neither beginning nor end, but always a middle (milieu) from which it grows and which it overspills.[...] In contrast to centered (even polycentric) systems with hierarchical modes of communication and preestablished paths, the rhizome is an acentered, nonhierarchical, non-signifying system without a General and without an organizing memory or central automaton, defined solely by a circulation of states.[...]" (ibid., p. 21)

If a system is analogous to a fully developed organism, then the rhizome is a system in its embryonic phase, except that there is no predictable path of development because the rhizome, unlike the embryo, does not possess the full code or programme of its unfoldment. There are unknown prospects that can be determined only through interactions with the rhizome's milieu. Here comes the second complementary concept of *Body without Organs* (chapter six). While the rhizome highlights the structural aspect of a parasystem – an embryonic existence undergoing individuation, Body without Organs (BwO) highlights the dynamism of individuation:

> "A BwO is made in such a way that it can be occupied, populated only by intensities. Only intensities pass and circulate[...] That is why we treat the BwO as the full egg before the extension of the organism and the organization of the organs, before the formation of the strata; as the intense egg defined by axes and vectors, gradients and thresholds, by dynamic tendencies involving energy transformation and kinematic movements involving group displacement, by migrations: all independent of accessory forms because the organs appear and function here only as pure intensities. The organ changes when it crosses a threshold, when it changes gradient. "No organ is constant as regards either function or position, ... sex organs sprout anywhere, ... rectums open, defecate

> and close, ... the entire organism changes color and consistency in split-second adjustments." [Quoted from burroughs' naked lunch]" (Deleuze and Guattari, 1987, p. 153)

The two concepts, rhizome and Body without Organs, frame an independent approach to complexity thinking. It is independent in the sense that it does not require a concrete entity, a system, or an organizing principle as a starting point. It also does not have to project a concrete outcome. These concepts allow thought as individuation to operate in its element without being subjugated to an *a priori* image.

6.5 Open-Ended Intelligence

If asked what is the single most significant motivation for the development of this thesis, the answer would, without doubt, be an attempt to find a new ground of thinking about intelligence (see chapter 12). Intelligence is not easy to define. There are two major ideas that have gained considerable traction in the discourse about the nature of intelligence. The first idea, as reflected by a comprehensive compilation of various definitions in (Goertzel and Wang, 2007), is that intelligence is the capacity to solve problems and achieve goals under changing circumstances. As such, intelligence can be observed in the behaviour of intelligent agents and in their interactions with the environment, where intelligent agents can be humans, other organisms, and a variety of artificial systems such as computers, robots and other devices. A second complementary idea, forwarded first by Howard Gardner in the 1980s (Davis et al., 2011; Gardner, 1984), is that there are multiple kinds of intelligence and there can be no single definition or measure of what intelligence is. In other words, intelligence as a capacity to solve problems should only be applied in relation to specific problem domains and not as a general concept. In all cases, however, intelligence is associated with cognitive and thinking skills such as pattern recognition, selection for relevance (attention), prediction, planning (taking into account long-term consequences of present actions), reasoning and decision making, coordination of actions and physical activities and more. Though Gardner's multiple intelligences initially related to human agents, in most cases they can be extended to animals and artificial agents.

In all these, intelligence is a capacity of an agent or a system and is associated both with thinking and cognition. In the first part of this thesis, we explored the possibility that both thinking and cognition can be understood in a much wider sense that derives from a radical metaphysical schema. If it is the case that thought as individuation is universal, there is also a case to associate with it a unique kind of intelligence which is universal. Such kind of intelligence need not be entirely alien to any of the ideas about intelligence mentioned here. In 4.2.3.1, virtual Ideas were described as problems and individuation as the process of creating solutions in the expression of actual forms. Though it was mentioned in brief, problematics is a theme which plays a significant role in the metaphysical thinking of both Simondon (resolution of problematic situations and disparity) and Deleuze. It is not a big intuitive leap therefore to propose that thought as individuation, being a problem-solving process, is intelligent. The proposition needs to be constructed carefully, however. The kind of intelligence associated with individuation is not and cannot be a capacity because there is in principle no agency to whom such capacity can be assigned. Furthermore, the nature of virtual Ideas as problems and the actualization of such Ideas as solutions cannot be considered as the achievement of goals because there is no one that has an *a priori* goal to achieve such solutions or any solution at all. Agents as well as specific goals (and the attempt or intention to achieve such specific goals) are already products of individuation. Descriptions deriving from such products are not applicable to the producing process. And yet, if there is anything that can be intimately associated with intelligent productive activity, it is actual forms of order – the products of individuation. Intricate patterns of order, or elegant and simple relations between multiple elements, are most intuitively accepted as manifestations of intelligence.

There is therefore a case to relate intelligence to individuation, but since the kind of intelligence that would fit such a case is not defined by a goal, a final reason, or a capacity to produce measurable results in a specific operational milieu (e.g., body coordination, human communication, survival skills in a certain environment, autonomous driving, optimal planning, winning Go games, etc.), it would be most appropriately termed *open-ended intelligence*. Open-ended intelligence is not something that gives itself to definition but it can be clearly inferred from its actual expressions. Inasmuch as everything thinks and is a thought, everything is inherently intelligent. But again it is a kind of intelligence which is not anyone's or anything's property or capacity. Open-ended intelligence is inherent in individuals in as far as they individuate, that is, in the course of expressing intelligence. An example may further clarify: when we observe an animal fit to its environment we see in it a manifestation of an evolutionary process. The intelligence associated with evolution is not the animal's intelligence; the animal itself (both form and behaviour) is the product of such intelligence that keeps on driving its individuation via specific processes of adaptation (i.e., the active preindividual). The intelligence underlying evolutionary processes is an exemplar of open-ended intelligence. There is no need to associate this intelligence with either its actual manifestations (the organism) or an imaginary agency (a "designer" or "creator").

Thought as individuation is unique and difficult because it is not a process that can be fully described. Even the designation 'process' is more like a figure of speech to signify a happening of progression from the undetermined yet determinable towards determination. It would not be accurate therefore to describe individuating processes as intelligent, that is, simply to apply to them an adjective, because it is impossible to reflect on them directly. If it were possible, this would imply that these are after all representations. The question remains of how to relate open-ended intelligence to individuation? Following the reasoning presented here, open-ended intelligence can only be understood as individuation itself, that is, not only a signifier of something else but the signified as well – the bringing forth of order out of non-order and of sense out of non-sense. This would of course mean that open-ended intelligence *is* individuation in action and also that individuation *is* open-ended intelligence in action.

Open-ended intelligence as a process (with the disclaimer above) may sound at first dissonant with the conventional meanings that are assigned to the word intelligence. But this is only a superficial impression. Open-ended intelligence is indeed a kind of intelligence radically different from all other kinds. While other applications of the concept are mainly of pragmatic empirical nature, open-ended intelligence is rooted in a metaphysical ground. It can only be inferred retrospectively from its products. Yet, it is argued that open-ended intelligence is more fundamental than all other kinds and notions of intelligence because these are already individuated to a higher or lesser degree. Again, we encounter here a case of an edge similar to the borderline between the unthinkable and thought and between the unknown and the known. Somehow the unintelligible becomes intelligible and this becoming, this differential, is open-ended intelligence. The designation 'open-ended' signifies inexhaustible possibility but it also signifies the incomplete and ungraspable in intelligence as it embraces also that which it is not and yet to become.

Open-ended intelligence is the last in a set of terms (thought, individuation, cognitive event, etc.) presented here that for lack of a better word can be called paraconcepts. A paraconcept (similar to parasystem above) differs from the conventional notion of concept in that the former is an embryonic form of the latter. It lacks the individuation that will allow it to be fully defined. There is indeed a sense of unease in regard to these terms because they can be palpated but not fully grasped and identified, and still one must speak of them using the language of identities as if they could be. This sense of unease is not superficial; it is a reflexive response invoked by the unequal that disturbs the organized universe of identities. The unequal – the unilateral internal difference – is what connects these terms and makes them resonate with each other. All of them reflect it: thought differentiates itself from the unthinkable yet the unthinkable remains undifferentiated from it. Knowledge differentiates itself from the unknown yet the unknown remains undifferentiated from it. Intelligence differentiates itself from the unintelligible yet the unintelligible remains undifferentiated from it. Difference, the metaphysical element that differentiates and connects, repeats in all the dimensions that develop from it.

Part II

Individuation, Cognition and Interaction

Prologue

Building on the metaphysical framework developed in part I, this part further develops the connections between individuation, a systemic concept of cognition and open-ended intelligence. By systemic concept of cognition I mean a concept that embodies the idea of the cognitive event from part I in a systemic context that can then be applied to a wide variety of specific systems and disciplines as demonstrated in the third part of the thesis. As was already remarked, individuation, dealing with the new as such (see quote on page 31), is a process that by its very nature does not give itself to complete formalization. But this is far from rendering it mysterious or useless. Treading on a fine borderline between what is formalizable and what is not, the goal is to lay down foundations to a framework where the borders between the known and unknown can be drawn *within the framework* and not as delimiting the framework itself. Such a framework will facilitate the application of the ideas presented in the first part – mainly thinking beyond representation and image – to actual systems, situations and problems.

Inasmuch as classical systems thinking can be considered to be an epitome of representation-based methodology, the introduction of such a framework anchored in an appropriate metaphysical framework expands systems thinking into the realm of complexity thinking. It allows aspects of actual systems that are not given to well defined closed representations to be addressed. The nexus of the framework is the process of individuation. Individuation in contrast to recognition always presents something novel or points towards places where novelty can potentially emerge. The novelty is where the connection between individuation and cognition is most apparent. Recognizing something must be preceded by cognition as an individuation process, that is, the formation of actual boundaries and distinctions. But this formative process is not limited to what is conventionally considered as cognitive. The resolution of disparity and the reciprocal determination of boundaries and interactions across boundaries in the course of such resolution is cognitive in the universal broad sense indicated in part I and is associated with open-ended intelligence. Such a concept of cognition admits a continuum of natural and artificial intelligent systems (see also chapters 11, 12).

The three chapters in this part develop three complementary aspects of the framework revolving around individuation. Chapter 7 develops the concept of systemic cognition as the individuation process of general systems. Chapter 8 focuses on the distributed nature of systemic cognition. Chapter 9 develops the concept of interaction as the fundamental mechanism underlying individuation.

Chapter 7

A Systemic Concept of Cognition

Modern cognitive science is an amalgam of quite a few disciplines of thought and research methods including psychology, philosophy, phenomenology, linguistics, anthropology, neuroscience, computer science, artificial intelligence and more, all aiming to understand the mind, its evolution and its workings. The study of the mind has roots as old as civilization itself but in its modern incarnation as the science of cognition it is barely more than half a century old. Perhaps naturally so cognition was initially studied in the context of human beings and living organisms as it was and to a large extent still is considered to belong solely to the living and is seemingly more pronounced in the human organism. To begin with, therefore, the study of cognition and the mind took an anthropocentric or biocentric (i.e., the study of cognition as a unique trait of the living) approach. One of the achievements of 20th century cognitive science is the establishment of a deep continuity and connection between life and mind (Thompson, 2007, pp. 157-162), which is best expressed in Maturana's proposition "living is a process of cognition" (Maturana and Varela, 1980). Yet other important attempts were made to further distill definitions and principles of cognition that would characterize general cognitive systems beyond the living as we know it and would also apply to complex systemic organizations, both natural and artificial, such as robots, computer systems, corporates, social networks, swarms and even more general processes of self-organization (Clark, 2013; Hoffman and Prakash, 2014; Krakauer et al., 2014; Malsburg, 1995).

In all these, cognition is characterized based on certain given structural and dynamic properties of systems. In this chapter, I will argue that if the etymological root and core meaning of cognition – *cognoscere* – to get to know, is to be taken to its limits, there is a deeper and more fundamental sense of cognition which is to do with the individuation of systems and the knowledge creation that precedes fully individuated organizations and is instrumental to their becoming. This sense of cognition underlies all forms of actual organization. It will be shown how this extended concept of cognition, already developed in 5.4.2, is deployed in the context of actual systems and how it is related to the contemporary enactive theory of cognition, which already goes a long way towards establishing cognition as an ongoing productive process.

7.1 The Enactive Theory of Cognition

7.1.1 A Brief Historical Context

From the start of the 20th century the study of the mind as a scientific endeavour has gone through a few phases or paradigmatic shifts that clearly resonate with the development of more general trends of western thought. The first phase, which can be roughly dated from the 1920s onwards, took the position that the inner workings of brains and minds are not given to objective empirical observation and therefore, according to the then dominant positivist approach to science, cannot become a proper subject of scientific research. Instead, science would better focus on behaviour, that is, learning the lawful relations that can be observed between inputs to the organism (stimuli) and outputs (behaviour). This, in a nutshell, was the research programme of behaviourism (Varela, Thompson, and Rosch, 1992, chap. 3). From the standpoint of behaviourism, cognition – the mechanisms of behaviour, is enclosed in an inaccessible black box and can at best be speculated about. In this sense, the behaviourist approach stood only as a negative precursor to cognitive science, proclaiming its impossibility.

The 1940s and the 1950s can justifiably be called a formative period of cognitive science with the emergence of cybernetics and the prolific range of new ideas that it brought to the investigation and modelling of living organisms and the mechanisms of their interactions with the environment (Ashby, 1960; Bateson, 1979). These included feedback mechanisms, regulation and homeostasis, self-organization, and more. With the advent of cybernetics cognition was no longer considered an opaque black box and new horizons for a science of the cognitive were opened. A decade of consolidation needed to pass before what can be properly called modern cognitive science was born around 1956 with the so called cognitivist hypothesis (Varela, Thompson, and Rosch, 1992, chap. 3) (Thompson, 2007, pp. 4-8). Cognitivism, one of the most prominent paradigms in cognitive science can be summarized as follows:

1. Cognition is a rule-based symbolic computation carried out by a system analogous to a digital computer.

2. Symbols are representations of states of affairs in the world including the possible sensorimotor interactions of the organism within such states of affairs.

3. Rules are either genetically hard-wired or programmed in case of artificial systems, or learned from experience.

4. The syntax of symbols and rules mirrors their semantics, i.e., what they represent. Therefore cognition need only involve syntactic manipulations of symbols and has nothing to do with their meaning.

5. Cognition is effective given that symbols indeed correspond to real states of affairs and the symbolic computation amounts to the organism solving problems

in the context of its actual environment (e.g., avoiding obstacles in movement, finding food, etc.).

We will not discuss here in detail the advantages and problematics of this cognitive model and its huge influence on neuroscience, psychology, linguistics, artificial intelligence and other disciplines. We only note here the strong correspondence between cognitivism and the image of thought that was discussed in chapter 2. Such correspondence entails that cognition amounts to forming a more or less faithful model of an *a priori* given world and devising proper responses to various stimuli via rule-based manipulation of the model. Additionally, for cognitivism to work one needs to assume a world given in terms of more or less discrete and predictable identities and their relations. In fact, cognitivism *is* a specific derivation from the image of thought that equates thinking to computation and perception/action to input/output operations.

Already in the early days of cognitive science, a paradigm competing with that of cognitivism was developing alongside but for various reasons did not rise to any significant prominence till the 1980s. This is the connectionist model of cognition (Bechtel and Abrahamsen, 2002),(Varela, Thompson, and Rosch, 1992, chap. 5),(Thompson, 2007, pp. 8-10). Contrary to cognitivism, which takes the digital computer as a core metaphor, connectionist models use as their metaphor the organic brain itself. Instead of a central processing unit, memory, IO ports, programs and data that comprised the so called von Neumann computer architecture[1], the connectionist core metaphor was a complex network of fairly simple interconnected functional elements working in parallel and corresponding to the vast networks of neurons constituting organic brains. There were a number reasons for the paradigm shift[2]. The most obvious one was that the cognitivist model was found by many too far removed from biology. The brain as a cognitive machine was massively parallel, resilient to noisy signals and local malfunctions and profoundly adaptive to varying tasks. None of these prominent characteristics could be easily demonstrated in terms of a computational model that is basically sequential, sensitive to local malfunctions and noise and requires meticulous algorithm redesign for anything but the most trivial adaptations. Moreover, biological brain circuits did not seem to realize processing and memory schemes that seemed to be paradigmatically essential for cognitivism.

In the connectionist paradigm of cognition there are no explicit rules, no symbols and most importantly no central control. Instead, simple local dynamics bring forth global coherent states and effects involving the whole network or large parts of it. The local elements are said to self-organize and together manifest cognitive functions that none of the individual elements can possibly realize. These functions

[1]The von Neumann architecture is to this day the basis for most digital computer designs. In this architecture complex computations are encoded into a set of simple operations that are carried out sequentially.

[2]This was rather the birth of a parallel complementary paradigm. Refined versions of both paradigms and a few others co-exist in contemporary cognitive science.

are termed *emergent properties* – global effects arising out of local interactions. The connectionist model can be thus summarized as following:

1. Cognition is the emergence of global self-organized states in a distributed network of simple elements with relatively simple local interactions.

2. The capacity of the network to globally perform various functions (e.g., pattern recognition, control, reasoning, etc.) is based on local rules of individual operation and how the elements are connected together.

3. Resilience is achieved by redundancy. No single element or even a small number of elements are essential to the realization of any global function. If individual elements malfunction, the deterioration of global performance is gradual and never abrupt.

4. Learning and plasticity are achieved via changes in connectivity. There is no algorithm design. The weakening and reinforcement of connections serve as a universal learning method via the reconfiguration of connectivity.

5. Cognition is effective when the network produces relevant output signals in response to input signals (e.g., is capable of effectively detecting and signalling the appearance of certain input patterns even in suboptimal conditions of noise).

The most important departure of the connectionist model of cognition from the symbolic one is that there is no clear sense of representation. The connectionist paradigm admits no internal models or representations of an outside given world. Instead, the network acquires a holistic model of the world and interacts through it. While the representation-based model assumes a world which is reducible to clear-cut elements and relations which are represented by corresponding symbols and relations, the connectionist model is non-reductionist. In the connectionist model meaning can only be understood in terms of the global state or a global stimuli-response relationships that do not provide explanation. While cognition in the cognitivist paradigm is something that can be reasoned about within a well defined conceptual framework and using the tools of logic, this is not the case in the connectionist paradigm[3].

Clearly, the connectionist paradigm makes far fewer assumptions about the world and about how cognition is realized. Yet from a certain perspective both paradigms suffer from a shared fundamental weakness. Thompson (2007, p. 10) argues that "Cognitivism and connectionism left unquestioned the relation between cognitive processes and the real world. As a result, their models of cognition were disembodied and abstract. [...] The mind and the world were thus treated as separate and independent of each other, with the outside world mirrored by a representational model inside the head." It is indeed true that the connectionist model does

[3]Recently vast artificial neural networks have been performing certain cognitive tasks better than humans but are incapable of providing an explanation as to how they reach results. In cases such as medical diagnosis or medical interventions, such opaqueness is of ethical concern.

not escape entirely the issue of representation. It only replaces a reductionist representation with a holistic one.

During the 1990s a new paradigm came to the fore called embodied dynamicism. Similar to the connectionist paradigm it focuses on self-organizing dynamic systems rather than on discrete symbolic manipulations. The core difference, however, is in approaching "the mind as an embodied dynamic system in the world, rather than the mind as neural network in the head." In simple terms, embodied dynamism sees cognition as a process taking place in the world *with* the world rather than a process about the world, yet isolated from it. Put otherwise, cognition is produced in the coupling between an embodied and situated mind and the world. This brings us to the idea of enactive cognition.

7.1.2 Preliminary Ideas

Enactive cognition was first clearly introduced in (Varela, Thompson, and Rosch, 1992). In its most fundamental sense enactive cognition is the hypothesis that cognition is the product of activity and more specifically of the activity of a cognitive agent in the world. It seems that the authors' primary concern was how the subject of cognition is embedded in a world being itself a product of cognition:

> "We reflect on a world that is not made, but found, and yet it is also our structure that enables us to reflect upon this world. Thus in reflection we find ourselves in a circle: we are in a world that seems to be there before reflection begins, but that world is not separate from us. (ibid., p. 3)"

This concern and the search of a cognitive model that would clarify the relation between the subject of cognition and the world was inspired in part by the work of Merleau-Ponty on the phenomenology of perception, who is quoted as saying:

> "The world is inseparable from the subject, but from a subject which is nothing but a project of the world, and the subject is inseparable from the world, but from a world which the subject itself projects. (ibid., p. 4) "

Another concern, already been mentioned above, was about the unwarranted assumptions made by both cognitivist and connectionist paradigms:

> "Thus in both cognitivism and connectionism, the unmanageable ambiguity of background common sense is left largely at the periphery of the inquiry, with the hope that it will somehow eventually be clarified. If, however, our lived world does not have predefined boundaries, then it seems unrealistic to expect to capture common sense understanding in the form of a representation–where representation is understood in its strong sense as the re-presentation of a pregiven world. (ibid., p. 148)"

Influenced by his work with Humberto Maturana on the biology of cognition (Maturana and Varela, 1980, 1987), and prior to the Embodied Mind, Varela puts together a few ideas that will later become the core of a new cognitive theory. In (Varela, 1987) Varela uses a poem by Antonio Machado as a metaphor to his idea that a cognitive agent *casts a world* while interacting with it:

> “Wanderer, the road is your footsteps, nothing else;
> wanderer, there is no path, you lay down a path in walking.
> In walking you lay down a path and when turning around you see the road you’ll never step on again.
> Wanderer, path there is none, only tracks on the ocean foam.”

The agent Varela has in mind is "an active, self-updating collection of structures capable of informing (or shaping) its surrounding medium into a world through a history of structural coupling with it." In cognition there is nothing given, either of the world or of the agent except for a history of coupling. Here we can already discern a parallelism with the concept of individuation (e.g., (Simondon, 2009, p. 8)) but we will return to it in more detail shortly. In more concrete terms, Varela brings up two foundational ideas that he weaves together: the ideas of autonomy and of natural drift, both of which have roots in prior work but now begin to acquire a new level of clarity and maturity:

> “I can now formulate the common ground of a "new" biology in terms of the key notions presented above. This common ground can be stated in terms of two crucial changes of emphasis.
>
> The first is putting the emphasis on the way autonomous units operate. Autonomy means here that the unit described (be it a cell, a nervous system, an organism, [. . .]) is studied from the perspective of (that is, uses as a guiding thread) the way in which it stands out from a background through its internal inter-connectedness. Such cooperation of self-organizing mechanisms can be made quite explicit in some cases, the research has just begun.
>
> The second change is putting the emphasis on the way autonomous units transform. Transformation means that natural drift becomes possible due to the plasticity of the unit’s structure. In its drift, adaptation is an invariant. Many paths of change are potentially possible, and which one is selected is an expression of the particular kind of structural coherence the unit has, in a continuous tinkering. Natural drift applies to phylogenetic evolution as well as to learning, depending on the unit being considered (a brain in one case; a population in the other). (Varela, 1987) ”

7.1.3 What is Enactive Cognition?

Most concisely, cognition is an embodied action that enacts – brings forth a world, where enaction means a history of structural coupling between the cognitive agent and its milieu. Such coupling can be operationally understood as perception that consists in perceptually guided action, or in other words, perception as an activity that itself is guided by outcomes of previous perceptions. In the course of such activity, cognitive structures dynamically emerge from the recurrent sensorimotor patterns that enable action to be perpetually guided (Varela, Thompson, and Rosch, 1992, p. 173).

In order to better understand what it means, it is worthwhile starting by contrasting the enactive approach to cognitivism. In cognitivism perception is understood as a problem of representing pregiven properties of the world. In enaction perception is understood as the problem of guiding the activities of the perceiving agent in its local situation. These local situations constantly change as a result of the agent's activity and therefore the world being perceived can no longer be assumed to be pregiven and independent of the perceiver's actions. Instead, the reference point is a sensorimotor structure or the set of relations that link perceptions to actions. This structure is what is meant by embodiment and will be further discussed in 7.1.4. It is embodiment and more specifically embodied interaction rather than a pregiven world that determines how the perceiver acts and how it affects and is affected by its milieu. The research programme of enactive cognition is thus concerned with studying the principles and lawful relations between sensory and motor systems that explain the cognitive structures that constitute an agent-dependent world.

What can be readily seen here is a deep embrace of the cybernetic idea and particularly a fundamental circularity of cause and effect. This embrace replaces the metaphysical separation apparent in cognitivism between world and mind, between what is present and what is represented, with a mind which is inseparable from the world and a world inseparable from the mind. Cognition is not internal to the cognitive agent in relation to an external world but rather takes place *between* the agent and its milieu. The agent and its milieu are "bound together in reciprocal specification and selection" (ibid., p. 174). Metaphorically speaking, enactive cognition is a coordinated dance performed by the agent and its milieu. Every action is both a response and a trigger to further stimulus. Behaviour – the form of the dance – consists of the recurrent patterns that appear within an ongoing unfoldment of intertwined causes and effects. A quote from Merleau-Ponty's *The structure of behaviour* sheds further light:

> "But it is the organism itself – according to the proper nature of its receptors, the thresholds of its nerve centers and the movements of the

> organs – *which chooses the stimuli in the physical world to which it will be sensitive.* The environment[4] (Umwelt) emerges from the world through the actualization or the being of the organism – [granted that] an organism can exist only if it succeeds in finding in the world an adequate environment. (Varela, Thompson, and Rosch, 1992, p. 174)"

The product of cognition is an environment which is neither an *a priori* given observer-independent world nor a construction or projection of the cognitive agent's mind. The environment is first and foremost an ongoing joint *actualization*, inseparable from the enactive agent or its milieu. This is further emphasized by Lewontin in the biological context:

> "The organism and the environment are not actually separately determined. The environment is not a structure imposed on living beings from the outside but is in fact a creation of those beings. The environment is not an autonomous process but a reflection of the biology of the species. Just as there is no organism without an environment, so there is no environment without an organism. (ibid., p. 198)"

Another profound theme which is prominent in the enactive approach is that cognition is not grounded in objects or relations that have a stable identity. Enactive cognition finds grounding only in a history of interactions and the recurrent patterns that arise in the course of such history. We will return to this in more detail in 7.1.6[5]. We are now in a position to further unpack the concept of enactive cognition by revisiting and giving further attention to the elements that constitute it: embodiment, the agency associated with cognition and structural coupling.

7.1.4 Embodiment

It is quite easy to confuse the concept of embodiment as it is deployed in the theory of enactive cognition with a number of earlier understandings of embodiment (Di Paolo, Rohde, and De Jaegher, 2010). The most common and obvious notion of embodiment derives directly from the digital computer metaphor where the mind is considered the 'software' implemented on the body as the 'hardware'. A similar separation exists whenever the mind is understood as a function that operates and is realized within a certain physical substrate or context, e.g., the control system metaphor where the mind is a controller that regulates the physical activities of the body. Another understanding of embodiment that falls short of the role the concept

[4]Notice the slightly different terminology here. The environment mentioned here is the enacted world mentioned above and the world mentioned here is the agent's milieu.

[5]It is interesting to note how a very similar line of thought can already be discovered in Bergson's ideas about cognition discussed in chapter 3. Bergson's concept of image, which is a kind of middle way between objective and subjective descriptions of reality and occupies a central role in his understanding of cognition, carries an interesting resemblance to the world brought forth by enactive cognition (Bergson, 1991, chap. 1) (also compare to (Varela, Thompson, and Rosch, 1992, chap. 8,10). Bergson's ideas predate the contemporary discourse of cognitive science by more than half a century.

plays in enaction is considering the whole body of the agent/organism as an extended information processing system that operates along with the central nervous system and is responsible for executing some of the computational tasks involved in cognition. Remarkably, such perceptions of embodiment still fall well within the cognitivist paradigm.

Embodiment in the context of enactive cognition is a compound of three sets: a set of sensors (and sensory processes), a set of actuators (and motor processes) and a set of structures that link and cohere between perceptual events in the first set to action events in the second. It is the specifics of these three sets that are determined by the history of structural coupling between the agent and its milieu. All three sets are self-updating in the course of the ongoing structural coupling with the agent's milieu as the embodiment of the agent is integral to the milieu that can be sensed and acted upon. This means that the agent's embodiment and its milieu are described within the same descriptive domain so their interactions can be described within that same domain too. If for example the milieu is described in the physical domain so is the embodiment and so are the interactions. Higher level emergent cognitive structures can always be grounded in terms of that same descriptive domain.

Di Paolo and Thompson (2014) emphasize an important attribute of embodiment as it is used in the context of cognition. In most cases and disciplines of study as well as in everyday conduct, they argue, bodies are individuated, that is, made distinct from their background just by some convention:

> "Many of the systems we study in science – particles, rivers, communities, galaxies, and even bodies – we typically individuate from the outside by convention, with varying degrees of accuracy. In other words, what counts as one system versus another typically depends on the conventional criteria we use to individuate the system; such criteria include considerations of convenience, perceptual biases, longer versus shorter relative time scales of change, semi-arbitrary definitions, of historical or practical use."

Yet irrespective to the conventional criteria applied to individuated bodies, in the enactive approach to cognition (as is already apparent from the quote on page 144), bodies are self-individuating, meaning that they actively generate and maintain a distinction between themselves and their milieu. The reference to an embodied cognitive agent in 7.1.3 is not the conventional reference to an agent as a centre of activity but rather that a cognitive agent is engaged (among other things) in self-individuating activity in relation to its embodiment. Any account of enactive cognition must therefore take into consideration that embodiment is meant in the sense of a self-individuating body, which brings us to the concept of autonomy and how such self-individuation is taking place.

7.1.5 Autonomy

The idea of autonomy has its roots in the theory of autopoiesis (Maturana, 1975; Maturana and Varela, 1980, 1987). Autopoiesis (translated as self-creating) is a theory defining living systems as systems capable of self-producing and self-maintaining their own organization. Autonomy is a more general concept that captures two related properties. The first is self-individuation, that is, the capacity of a system to distinguish itself from its milieu, the second is the capacity of the system to specify its own laws and norms applied in its interactions with the rest of the world. Of course specifying its own laws does not mean the system has unconstrained control over its milieu, but only that it is capable of selecting some of its actions and responses according to such laws. Living systems are perhaps the best examples of autonomous systems. The autonomy of living systems is achieved through their autopoiesis but this is not the only way autonomy can be realized.

It is evident, though to this point not explicitly, that a cognitive agent is not just an arbitrary collection of sensors and actuators somehow coupled to each other. What constitutes a cognitive agent is a collection of sensors, actuators and additional components organized in a manner that is self-individuating and regulating its activities/interactions according to internal norms that are aspects of its self-individuating organization. Di Paolo and Thompson (2014) write:

> "For the enactive approach, a system is cognitive when its behavior is governed by the norm of the system's own continued existence and flourishing. Basic cognition, on this view, is not a matter of representing states of affairs but rather of establishing relevance through the need to maintain an identity that is constantly facing the possibility of disintegration."

How is autonomy realized? An early notion of autonomy as a generalization of autopoiesis and differentiated from it appears in (Varela, 1979). Central to the realization of autonomy is the concept of *operational closure*[6]. Consider a set P of interconnected elements or processes (e.g., sensors, actuators, and other mediating components) all described in the same operational terms, meaning that their structure and mutual interactions (how they affect and are affected by each other) are given in the same terms. The set is said to be operationally closed if and only if the operation of each and every process in P is *a*) a condition for the operation of one or more other processes in P and *b*) is conditioned by the operation of one or more processes in P (see figure 7.1). If these relations hold, the set P forms a network of processes conditioned by each other in such a manner that the overall operation of the network is necessarily maintained by the operation of each and every component in the network and the network is thus operationally closed. Operational closure, however, does not mean that the overall operation of the network P is independent of other processes that are not part of it. Certain external conditions might

[6] In the literature the terms operational closure and organizational closure are used interchangeably.

still be necessary for the operation of the closure's components. Additionally, the operations of components in the closure might be a necessary condition to other processes that do not belong to P (Di Paolo and Thompson, 2014, pp. 2-6). This relation of mutuality can also be thought of as some form of organizational coherency or synergy that distinguishes the set P from the background of all other processes. Therefore, operational closure can be said to realize a self-individuating entity, or in other words, it produces and maintains its own identity[7].

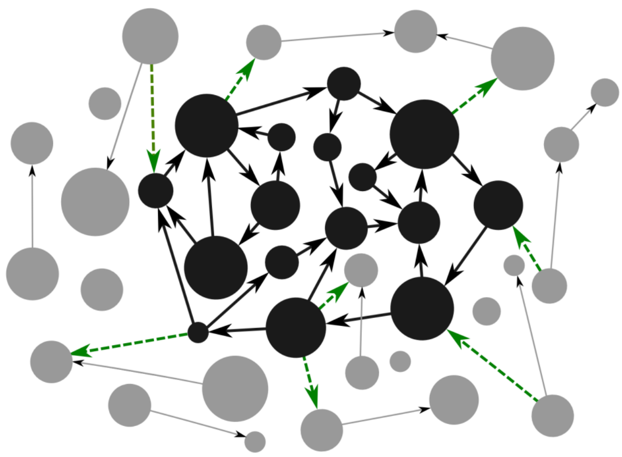


Figure 7.1: A a schematic illustration of an operational closure. The black circles belong to the closure whereas black arrows signify enabling dependencies and green arrows signify dependencies external to the closure.

Di Paolo (2009) presents the interesting argument that a definition of autonomy based solely on operational closure is not sufficient to reflect the full power of the enactive approach. The argument concerns not so much self-individuation but the second requirement for an autonomous system to establish its own norms of operation. Di Paulo argues for a stronger kind of autonomy, which he calls *a precarious autonomous system*. Precariousness means that the processes constituting the closure must have the property that once they are partly or fully isolated from the closure they participate in, they will tend to degenerate and cease. In other words, the operationally closed organization is critical to the maintenance of its component constituents as well as to the maintenance of their joint organization. In a precarious autonomous system, the closure as a whole operates *against* the otherwise natural tendency of the component processes to degenerate. In this, the closure fulfils a much stronger role than just maintaining itself, it actively enables itself. "[I]t produces its own preconditions." To illustrate, the autonomy of the human organism is such that it relies on the operational closure of various organs. Metabolism cannot proceed without a heart, a liver, lungs etc. Autonomy under circumstances of

[7]Notice that closures can be nested and form complex autonomous systems.

precariousness means not only that the whole body, as distinguished from its milieu, cannot self-maintain, but also that the maintenance of each and every organ depends on the overall closure. Not only can I not keep on living without my liver, my heart, my lungs, brain and such, but also these cannot keep functioning outside the closure of my whole body. In other words, "[a] precarious autonomous system, at whatever level, intervenes in its own substrate in order to sustain a form which is made out of components that paradoxically provide the very tendencies towards the dissolution of the same form."

Why is this important? In working against the tendencies of the component processes, the autonomous system as a whole must operationally assert certain norms in relation to its component processes and in relation to the interactions between these processes and other processes that are external to the autonomous system. In short, it is only on the basis of a precariously generated identity that an autonomous system can assign a non-trivial significance to its various interactions with its milieu (interactions actually performed by its component processes) as these become critical to its very continuation. Put differently, the precariousness of identity in autonomous systems is instrumental to the establishment of norms and the regulation of activities according to such norms. A precarious autonomy possesses another nuanced property that is worth noting. Each process in the closure is only viable if conditioned and facilitated by interactions with other processes in the closure. The special property achieved under such critical dependencies can be termed *operational coherency*. Operational coherency is truly emergent in the sense that it is neither a property of the component processes, nor strictly a property of the closure as a whole because there is no point to assign it to the whole without reference to how it is achieved internally. It is therefore a property of the compound relations of the whole with its components while remaining independent of both the specific closure and its specific realization via a set of specific processes. Operational coherency is especially significant in the case of fluid identities discussed in 7.2.4.

With this understanding of autonomy we can now appreciate that a cognitive agent is not just structurally coupled to its milieu. There is a profound asymmetry in this coupling as the agent, as an autonomous system, is normatively regulating its own interactions to enable and maintain its own identity. It is said therefore to be engaged in *sense-making* (see 7.2 ahead) in regard to its milieu (Di Paolo, 2009, p. 9), (Di Paolo, Rohde, and De Jaegher, 2010, pp. 37-39).

In summary, we learn that operational closure provides the explanatory ground for enactive cognition. What we need further to account for is how autonomous agents engage with their milieu and in what manner they affect and are affected by such engagements as to bring forth a world.

7.1.6 Structural Coupling and Natural Drift

Structural coupling is a term describing the interactions of a cognitive agent with its milieu. Two structures are said to be coupled when there exists a history of reciprocal perturbations between the structures. In our case it is the structure of the cognitive agent and the structure of its milieu that interact by exchanging perturbations. The perturbations produced by the milieu trigger changes in the structure of the agent, e.g., by producing an excitation in some sensory organ. But importantly, the perturbations themselves (e.g., a sudden increase in the intensity of ambient light) are not instructive as to the nature of change that they have triggered. Such changes are determined by the structure being triggered (e.g., contraction of the iris in the eye determined by the anatomy of the organism) and in some cases such structural changes elicit actions that introduce further perturbations to the milieu. When such exchanges of reciprocal perturbations become recurrent, there is a history of structural coupling between the structures as they share an ongoing exchange of perturbations (Maturana and Varela, 1987).

Enactive cognition is said to be realized as a structural coupling between the cognitive agent and its milieu. According to the core definition in 7.1.3, enaction is a history of structural coupling. Now we are in a better position to further understand what it means. The cognitive agent is an embodied autonomous system that dynamically maintains its identity. This self-individuating activity does not take place in a vacuum but rather by an ongoing engagement with a milieu with which the agent exchanges perturbations. The maintenance of identity can be understood as a teleological directive that guides the agent's interactions with its milieu (Di Paolo, 2006).

As a first approximation, an autonomous system may undergo many structural changes while maintaining its operational closure, that is, its identity. The set of all structures that are still mapped to the same autonomous organization are termed the system's *viability set* (Di Paolo, 2009, pp. 8-9). The perceptually guided actions that constitute enactive cognition are directed towards increasing the probability of perturbations that trigger structural transformations that are well within the system's viability set and avoiding perturbations that trigger structural transformations that lead out of the system's viability set as well as decreasing the probability of the future occurrence of such perturbations. Only on account of autonomy do perturbations gain significance in relation to the agent's state of affairs. Moreover, perception, inasmuch as it can be guided by action, can be dynamically positioned towards the milieu in such a fashion as to better inform future actions based not only on the immediate perturbations but also on the tendencies of future perturbations to be beneficial or detrimental to the agent's autonomy. This is how the actions of the agent become not only perpetually guided by its perception but also anticipatory. Hence enacted cognition.

In the course of such activity cognitive structures emerge dynamically from the recurrent sensorimotor patterns, e.g., changes in the contraction of the iris in response to changes in lighting, avoiding collision with obstacles while moving, running away at the sight of a predator, or singling out suspicious activities in credit cards. The cognitive structures that emerge can become significantly complex. Together they constitute for the agent the environment it brings forth, which is significant to the maintenance of its autonomy and is practically inseparable from it. What is missing from such environment is either entirely insignificant for the agent, i.e., activities that do not trigger any structural changes in the agent, or has no previous record in the history of its structural coupling, i.e., those surprising events in the world that do not make sense as yet and therefore are not part of the agent's environment. It is important to note that the actions of the agent also shape the agent's milieu and indirectly transform it to fit the agent's activities. Consequently, the environment and the agent display a remarkable fitness to each other, so the environment brought forth cannot be said to reside entirely inside or outside the agent.

The concept of cognition we have arrived at is pretty fluid in the sense that cognitive structure only reflects a history of coupling. However, some derivative views that accept that both embodiment and perceptually guided activity enacted by an history of structural coupling are essential aspects of cognition still raise the objection that the history of coupling is not arbitrary. The coupling and its emergent cognitive structures are constrained by natural selection so as to confer some survival value or fitness on the agent in line with the theory of evolution. In other words, such an objection would claim that there is a pregiven world and cognitive structures having evolved by natural selection reflect some optimal fit to such world. The subtle issue here is that the enactive approach to cognition claims that histories of structural coupling can culminate in very diverse cognitive structures that bring forth diverse environments that are, to a large extent, unique to the cognitive agents that bring them forth. The counter claim is that the diversity of such environments is ultimately constrained by natural selection in order to optimally fit a pregiven objective world (Varela, Thompson, and Rosch, 1992, pp. 180-184). In other words, that the diversity of environments is merely a diversity of perspectives on an objective world adopted by various agents. This kind of objection does not reject enactive cognition but rather deprives it of its more radical and powerful claim.

Tackling this objection (ibid., chap. 9) highlights an interesting parallelism between cognition and evolution (see also: (Heylighen, 1991)). In the same manner that a cognitive agent is self-individuating and in that brings forth a world, so by analogy the evolution of a biological species can be said to be a case of self-individuation where a species brings forth a world - the ecosystem or environment in which it survives. Evolution can therefore be seen as a cognitive activity but at a different time scale and with a different kind of agency. This parallelism lends ground to the hypothesis already developed earlier in the thesis about the intimate connection existing between individuating systems and the concept of cognition. This relation and the bridge provided by enactive cognition is further developed in 7.3. Meanwhile, we attend here to a deeper understanding of structural coupling that defends the theory against the objection just described.

Concisely, the argument is that a correspondence between an organism and its environment must be presumed to exist based on the optimizing constraints of survival and reproduction that are guiding its evolution. By analogy, and assuming that cognition is a product of the same general evolutionary constraints, the same reasoning can be applied to defend the idea of representation in cognitivism: cognitive structures must correspond one to one to states of affairs in the world simply because any other option will be detrimental to the survival and continuation of the species (Varela, Thompson, and Rosch, 1992, pp. 193-194). The thrust of the counter argument is that it is hardly tenable that the constraints of survival and reproduction suffice to provide a full account of all the details of evolved traits. The computational difficulty[8] in finding a global optimal fitness in a very complex system of interconnected traits does not contribute to the overall plausibility of the optimization argument. The burden laid upon natural selection to explain every single trait of every single organism ever as contributing to fitness seems indeed overwhelming. The alternative explanation the authors propose appeared initially in (Maturana and Varela, 1987) and is based on the idea of evolution as natural drift. In a nutshell what this would mean is:

> "to switch from a prescriptive logic to a proscriptive one, that is, from the idea that what is not allowed is forbidden to the idea that what is not forbidden is allowed. In the context of evolution this shift means that we remove selection as a prescriptive process that guides and instructs in the task of improving fitness. In contrast, in a proscriptive context natural selection can be seen to operate, but in a modified sense: selection discards what is not compatible with survival and reproduction. Organisms and the population offer variety; natural selection guarantees only that what ensues satisfies the two basic constraints of survival and reproduction. This proscriptive orientation shifts our attention to the tremendous diversity of biological structures at all levels." (Varela, Thompson, and Rosch, 1992, p. 195)

This allows evolutionary processes to be treated as *satisficing*, that is, selecting "good enough" solutions rather than optimal ones. "Here the evolutionary problem is no longer how to force a precise trajectory by the requirements of optimal fitness; it is, rather, how to prune the multiplicity of viable trajectories that exist at any given point." In other words, much of what constitutes an organism or the world brought forth by cognition is under-determined by the constraints imposed by the milieu. There is therefore a vast space of variability for individuation to take place. Evolution (and likewise cognition) as natural drift is a process taking place within an history of structural coupling and where structures drift within their viability set while being pruned from time to time to select out trajectories that are not viable. "The crucial point here is that we do not retain the notion of an independent, pregiven environment [read as milieu, world] but let it fade into the background

[8]The computation is in fact intractable.

in favour of so-called intrinsic factors[9]. Instead, we emphasize that the very notion of what an environment is cannot be separated from what organisms are and what they do." (Varela, Thompson, and Rosch, 1992, p. 198) Notice that in all this, natural selection remains a prime player in evolutionary explanations. Moreover, under circumstances where the viability set is particularly narrow, or where good enough variations still carry a differential advantage, even a small one, in relation to a stable milieu, the proscriptive interpretation of natural selection will still converge eventually towards optimal solutions.

This brief and condensed discussion boils down to a point which is critical to the understanding of enactive cognition and how it connects to the bigger picture drawn in the first part of the thesis: based on the abstract mechanism of structural coupling (described in whatever operational domain), cognitive agents and their milieu stand in relations of progressive reciprocal determination that realize their ongoing individuation. Identities, objects and recurrent patterns of behaviour (habits) all arise from a play of perturbations – differences that trigger other differences – that is, intensities, as described in 4.2.1. In enactive cognition as a systemic theory we find therefore a candidate for an actual mechanism that accounts for the emergence of identities out of recurrent and reciprocally determining series of differences. It is this alignment of the systemic and metaphysical that lends significance to the idea of evolution as natural drift. Without this alternative interpretation we could not escape from positing a pregiven world, which is equivalent to positing an identity that precedes difference. We return to this issue and the difficulties it raises shortly as we attend to the final and most fascinating aspect of the enactive approach – sense-making.

7.2 Sense-Making and Boundary Formation

7.2.1 A Whole World Unto Itself

The simplest example of sense-making can be observed in bacteria swimming upward of a sugar gradient. Sugar is significant to the bacteria and it would better to have more of it than less because of the way sugar is used by the bacteria's metabolism to maintain its autonomy. The significance of sugar is not intrinsic to its chemical compound but is rather derived from the relation between the chemical and the bacteria as an autonomous agent. The significance or meaning of sugar arises in the course of the bacteria enacting a world via its structural coupling with its milieu. The example shows that even primitive organisms transform the world via their interactions into a place of salience, meaning and value – an environment (Umwelt) (Thompson and Stapleton, 2008).

In general, autonomous systems regulate their structural coupling with their milieu so as to direct the unfoldment of such coupling towards the maintenance of their

[9] It is not entirely clear what exactly are 'intrinsic factors' here, I would replace the term with 'contingent factors'.

identity. In that they "cast a web of significance on their world [...] establish[ing] a perspective on the world with its own normativity [...]" (Di Paolo, Rohde, and De Jaegher, 2010, p. 39). In other words, they make sense of their milieu and bring forth their environment as sensible with its intrinsic meaning and value. The invariants (e.g., objects, relations, behaviours, know-how) that appear as the products of cognition in the agent's environment are an outcome of a joint dynamism of agent and milieu. These already appear with an intrinsic significance according to their relevance for autonomy. Cognition as an activity of sense-making is therefore never only about acquiring information and processing it in an objective manner that falls well within what is understood as computation (i.e., information in the sense developed by Shannon (Shannon, 2001)). Cognition, instead, brings forth information in the sense discussed in 5.1.3.3. It creates information rather than just manipulating it and the kind of information created has its own intrinsic significance – it is information about something for somebody.

Di Paolo (2009) sketches a more detailed scheme of what would seem necessary for sense-making to take place under the term *adaptivity*. It is not sufficient that an autonomous system will be able to respond to perturbations by transformations of its structure that are well within its viability set. As was already implied above, the system will gain much advantage in maintaining its autonomy if it can monitor the tendencies of the current perturbations it is exposed to and anticipate whether such tendencies lead its current trajectory of structural changes towards or away from the boundaries of its viability set. If such anticipation is possible, the system can act in advance so as to regulate its own structural coupling, modifying prospective harmful trajectories into beneficial ones (see figure 7.2). This kind of regulation, Di Paolo argues, can be considered as the hallmark of sense-making activity and of cognitive agency. Only an adaptive autonomous system can be said therefore to be a cognitive sense-making agent.

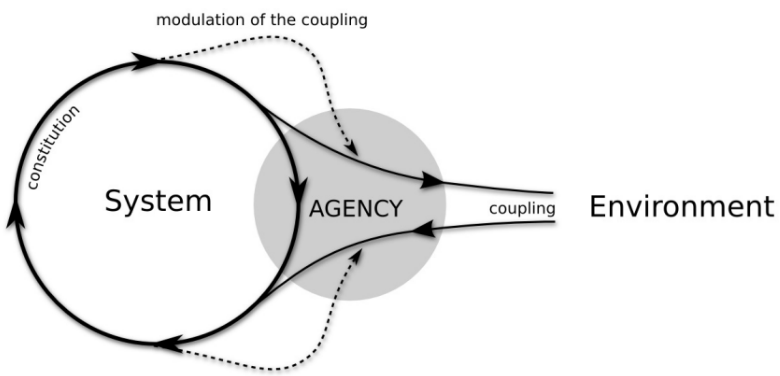


Figure 7.2: An illustration of a cognitive agent. [Copyright 2009 Xabier Barandiaran under Creative Commons Attribution Share Alike license, freedom is granted to copy, modify and redistribute this work provided that this notice is preserved]

This notion of sense-making can be well understood and explained in terms of cybernetic regulation based on self-created norms (Ashby, 1960, chap. 3-7). Such norms if made explicit also provide a set of defining (invariant) properties for an identity. Yet, arguably this concept of sense-making is problematic for a number of reasons:

1. Sense-making only 'makes sense' on the basis of an existing autonomous system. It must assume a preexisting identity from which norms are derived. In other words, there must be something or someone who makes sense and for whom things or situations acquire significance. With all the effort of escaping a pregiven world this whole line of thinking falls back to assuming a pregiven identity. To put it more boldly, the world enacted and brought forth in cognition is a projection of an *a priori* identity. Every identity is a whole world unto itself. The enactive approach indeed establishes a plausible story of how autonomy can be explained in terms of an operational closure and how cognitive activity ensues. An interesting if not a critical part which is missing from the story, however, is how cognition develops from non-cognition, that is, how closures are brought forth. After all the highest significance cast by the agent is assigned to its own identity, which it actively pursues to maintain. But how do cognitive systems come to make sense of themselves in the first place? This is where the story told above is found wanting.

2. Even given an *a priori* identity that casts a web of significance as explained, it is not clear how the cast web of significance and regulation of structural coupling bring forth individuated entities. That is, how do they constitute actual distinctions of objects, relations and behaviours that populate an enacted richly textured world like the one we experience? The question here is not about particular mechanisms but rather about a story that accounts how cybernetically regulated interactions give rise to a rich world of distinct objects, relations and behaviours.

3. When self-individuation and adaptivity are combined it is no longer clear whether the maintenance of identity must mean the continuation of the same identity or the continuation of any identity. Adaptivity understood as keeping structural transformation within a viability set can be achieved not only by regulating structural coupling with the agent's milieu but also by reshaping the viability set itself. In such a case, as will be shown shortly, new options for sense-making that are not accounted for by the above story become available.

Trying to answer these questions inevitably leads to stretching the enactive approach beyond its current limits. Can we conceive of sense-making without sense-maker and enacted cognition without an actor?

7.2.2 Sense-Making sans Maker

As already mentioned, the enactive approach to cognition is rooted and strongly influenced by the theory of autopoiesis. Autopoiesis indeed provides an account of how living systems *are* but not how they *become*. This apparent weakness seems to have diffused into the enactive theory of cognition. The beginning of life is itself an open question both theoretically and empirically. It provides little or no useful clues as to how to address the formative aspect of sense-making. Considering sense-making that precedes autonomy is therefore treading uncharted grounds in a double sense. It is definitely not covered by the literature on enactive cognition and it aspires to glimpse beyond a world charted by already consolidated identities.

A way to approach the problem is to shift from the logic of individuals to the logic of individuation. As already discussed in 7.1.5, an autonomous system is self-individuating. But in fact, the literature describes an autonomous entity as *self-individuated* rather than self-individuating. The difference is that a self-individuated system is a system that maintains its own individuality once such individuality is already given. Self-individuating, we argue, has a wider sense, describing a system capable not only of maintaining identity but also of undergoing transformations of identity without losing its overall coherence and integrity. If we assign this extended meaning to autonomy, inevitably sense-making becomes a formative process. It is not merely the activity of maintaining an already existing identity but rather a transformative process of an identity continuously in the making. Once enactive cognition is acknowledged as formative it can be thought of as consisting of two interwoven aspects: the bringing forth of a world and the bringing forth (individuation) of identity. We associate the latter with *cognitive development* (further discussed in chapter 11).

Similarly this would mean that sense-making is not just the bringing forth of a significant world based on a system of identity-bound norms. Sense-making is a process where identity and its generated norms – the norms that cast significance on the world – may undergo transformations. It is as if sense-making turns upon the sense maker itself, which becomes variable, i.e., it can differ from itself in the course of sense-making. Undoubtedly this is a difficult conceptual exercise, primarily because it does not leave any solid basis neither in a pregiven world nor in a pregiven identity. Invariant entities, i.e., particular operational closures, are replaced by shape-shifting entities walking on shifting sands. This goes yet a step closer than the poetic metaphor by Antonio Machado in 7.1.2 to the profound impermanence underlying all existence (see also (Varela, Thompson, and Rosch, 1992, pp. 241-245)). Yet, contemplating the idea of sense-making sans (fixed) maker and cognition that brings forth both a world and agent does not discard but extends the ideas discussed thus far. One need only to accept that the only ground is a metastable ground. From a history of structural coupling (given as past experience) one can only infer invariance but never establish it logically.

If the becoming of the cognitive agent is an ongoing transformation, the processes that actually cause operational closures to form or disintegrate are not fundamentally different from the processes that cause such closures to undergo transformation. These will involve component processes joining or separating from the closure and the formation or elimination of dependencies without the overall closure property being lost, or even more liberally, without it being lost for long enough for any of the precarious component processes to irreversibly cease[10].

Extending the scheme of enactive cognition beyond reliance on pregiven autonomy requires answering the following questions: *a*) What would be the meaning of sense-making that precedes autonomy and brings it forth? *b*) What is the possible (abstract) mechanism of sense-making that does not presume autonomy? These questions are discussed in 7.2.3 and further in 7.3; *c*) How can sense-making be redescribed as an ongoing formative process, i.e., as truly self-individuating? This question is discussed in 7.2.4; The rest of this chapter (and parts of the following ones) presents work in progress in an attempt to extend the meaning of cognition, taking the enactive approach explored to this point as the point of departure.

7.2.3 Boundary formation

A boundary is a geometrical (or rather topological) analogue of distinction. A boundary drawn within a set of points distinguishes between a subset of points possessing some property X and a subset not possessing that same property. The concept, therefore, is closely related to the concept of individual. In as far as an individual entity is distinguished from its milieu in any arbitrary fashion, there exists a property space where both the individual entity and its milieu can be represented as separated by a boundary. Extending the analogy, the idea of boundary formation intuitively corresponds to individuation.

Let us reexamine the concept of structural coupling that serves as the mechanism of enaction. What we have at hand are two structures perturbing each other and undergoing structurally determined transformations. The coupling is the result of an history of recurrent reciprocal perturbations. What is implicit in this story is that there is a boundary that distinguishes one structure from the other and across which perturbations can be said to take place. If such a boundary does not exist there is no point in talking about coupling (coupling between what and what?). If there is a boundary in place, some degree of individuation is already actualized.

It is proposed here that the meaning of sense-making that comes prior to self-individuated entities is the process of boundary formation, that is, the spontaneous emergence of a system-milieu distinction in a network P of interacting processes. In the simplest case, the subnets of processes P' and $P - P'$ distinguish themselves from each other, forming a boundary between them. The specific nature of the distinction

[10]E.g., we are well familiar with the fact that people can be brought back to life from a condition of clinical death within a certain critical window of time without any significant long-term impact on the system.

is less important at the moment. What is important is that the boundary is intrinsic to the network and not imposed by an external observer. Once there is a boundary, interactions among the members of the network gain a distinctive significance: they can be categorized as interactions taking place across the boundary, or interactions not taking place across the boundary[11]. The formation of a boundary casts therefore a primitive significance over P and hence it can be considered as a primitive event of sense-making. What such spontaneous sense-making allows is the consideration of structural coupling prior to autonomy and independently of an observer external to the network. This is far from being trivial.

The partition of a network of interacting processes into subnets is initially serendipitous and possesses no intrinsic tendency to persist. For example, partitioning can be the effect of the non-uniformity in the distribution of interactions where processes in one subnet interact much more with other processes of the same subnet than with the processes in the complementary subnet. If processes happen to affect each other, i.e., trigger structural changes in each other, the incidence of interactions may become at times self-reinforcing, i.e., increasing/decreasing the probability of recurrence, and by that driving the formation of distinct boundaries. Yet there need be no *a priori* tendency or selective pressure towards some given norm that pushes towards boundary formation. In a large enough network of interacting processes which is also richly heterogeneous and diverse, natural drift of randomly interacting processes is sufficient to assemble from time to time partial closures (still lacking some components to become fully closed), simple reciprocally determining processes, reciprocally enabling processes etc. Such entities may persist for a while or even indefinitely without being self-individuated closures simply because they happen to be left unperturbed. Such persistence is enough for closures to form gradually, but more critically, it is enough for many bodies to persist even without active self-individuation. Tendencies can develop in the course of such initially random interactions provided that there is sufficient non-uniformity in the network.

Three general points need to be remarked here whereas a more detailed discussion about the mechanisms involved is left to chapters 8-9:

1. Boundary formation cannot be given a formal description, precisely because it attempts to chart the place where distinctions arise and cannot be presumed. The same reasoning as to why processes of individuation cannot have closed formal descriptions applies to boundary formation processes as well. Boundary formation is not entirely organized but serendipitous at least in part. If the formation of a boundary can be deduced from prior assumptions it is not boundary formation in the sense meant here.

2. With all its intrinsic vagueness the story of boundary formation makes a plausible case that there is enough time and opportunities for closures to form, that is, for identities to just arise even without any *a priori* guidance, design or

[11] In some cases an additional designation of within/without boundary can be assigned.

purpose. In other words, operational closures are far from being all-or-none entities. There is a rich world of pre-individuated, pre-autonomous entities, unstable or partly stable, from which autonomous entities may appear (and into which also disappear) in a serendipitous gradual process, i.e., a more or less lucky chain of accidents.

3. Boundary formation as described here is an effect of interactions among already individuated processes and the same investigation as to the individuation of these processes can ensue recursively. The formation of boundaries is only conventionally confined to a certain domain of descriptions but beyond such conventional constraints, boundary formation processes may take place simultaneously across multiple scales and multiple descriptive domains.

7.2.4 Fluid Identities

The idea of fluid identities is an extension of enactive cognition based on replacing the notion of individuals with individuation. By definition, a precarious autonomous structure requires an operational closure to be maintained continuously in the course of structural coupling. This requirement can be restated in a very significant manner: a precarious autonomous structure requires its operational coherency to be maintained in the course of structural coupling. This means that critically the very property of closure must be maintained but it does not necessarily mean that *it is exactly the same closure that is maintained all along*. Operational coherency is not conditioned by the identity of the component processes of the closure but rather by an overall alignment of their dependencies. As a result, identity can radically change its defining properties while maintaining an inner operational coherency. In the course of such changes, identity can be said to evolve or undergo cognitive development. Both refer to the same systemic process but from a different context, which is mostly a matter of convention.

To illustrate, consider a series of distinct structures $C_1, C_2, \ldots, C_i, \ldots$ each realizing an operational closure. Each structure in the series shares with its closest neighbours most of their constituent processes but they are still significantly different from each other. Suppose, for example, that two adjacent closures C_i and C_{i+1} differ in only a single component as process P_{c_i} in C_i is replaced with $P_{c_{i+1}}$ in C_{i+1}. The replacement is such that the new process is still providing the conditions provided by the old one to the maintenance of the closure but differs from the old one in the specific processes that are necessary for its own continuation within the closure. What has changed? While autonomy is uninterrupted (supposing that the new process appears before the old one disappears), the transformation is not merely structural. The very identity of the autonomous agent has changed, its norms have changed and so has its viability set. Were some adverse external perturbations to be present with the effect that P_{c_i} has ceased and consequently C_i loses its autonomy, this situation would no longer apply to C_{i+1}. This example demonstrates how the operational coherency of the closure can be maintained while identity changes. Consequently, the cognitive activity and the world enacted change.

Following this line of reasoning, precarious autonomy is maintained globally across the series $[C_i]$ but not locally due to the fact that certain processes do cease to participate in the closure while others join it. If the changes occurring between neighbours are relatively small, that is, most of the structure remains unchanged, the series $[C_i]$ can then be considered as representing a single individuating agent with a *fluid identity*. A fluid identity keeps most, yet not all, of its operational properties when it locally drifts from one organization to another (notice that the change must be organizational and not merely structural for identity to deserve the designation fluid). A slow drift of operational properties, given enough time, can accumulate into major differences, i.e., the changes from C_i to C_{i+k}, where $k \gg 1$ can be radical, meaning that fluid identities (and their enacted cognitive sphere) are capable of radical transformation.

Fluid identity is the only proper description for a continuously individuating autonomous agent. Additional to structural changes within its viability set, it may gain or lose component processes in the course of its interactions. Some such interactions bring forth novel operational closures modifying the viability set while preserving autonomy, while other interactions might be more disruptive causing temporary but not fatal gaps in the sustained closure (and autonomy) but soon enough establishing a new closure. In a world populated with complex systems with complex interactions such transformations happen all the time. That we tend to describe the world in terms of stable identities is only a habit. Stable identities arising from stable operational closures are special (and relatively rare) cases of fluid identities where a system has become (almost) crystallized or is just changing very slowly compared to its surroundings, or observers.

In the extended version of enactive cognition there is a continuum of sense-making activity that can be divided into phases from the relatively vague preindividual boundary formation phase, through the fluid identity phase, to highly individuated (i.e., high level of determination) self-maintaining adaptive identities. This continuum is also reflected in the history of structural coupling. In the phase of boundary formation, the incidence of recurrent patterns is relatively low, while moving towards the phase of highly individuated agents such incidence tends to increase and more recurrent patterns of interactions will be found. Again, it is important to note that boundaries can form and passively persist indefinitely in the absence of disrupting perturbations (natural drift). Stable individuals thus formed need not necessarily reach autonomy in the strict sense described above. They nevertheless still resist change due to the configuration of their interactions and in this sense can be said to passively self-maintain. There is a continuum between passively persisting individuals and actively adaptive ones.

The movement between phases has no particular direction. Processes of integration and dissolution of individuals at multiple scales follow each other as cognition unfolds. On the thick borderline between preindividual boundary formation and fully established individuals, fluid identities exist that are manifestations of more or less balanced proportions between recurrent and contingent interactions in the course of structural coupling.

7.3 Cognition and Systems

The theory of enactive cognition deploys many of the ideas explored in the first part of the thesis in the context of systems. Clearly, the enaction of cognition is a dynamic event which is the system-theoretic counterpart of the metaphysical event of cognition mentioned in the introduction, in 5.4.2 and other places. My aim here is to highlight the significance of the concept of cognition and cognition as sense-making to the way we think about complex dynamic systems. The cognitive approach to systems can in first approximation be considered as extending the more classical cybernetic approach to systems and their self-organization (Ashby, 1957, 1962; Heylighen, 2013). The extension consists mainly of the formative evolutionary aspect of actual systems that comes into play in processes of boundary formation and transformation of identity. The very concept of system already indicates an organization of more or less stable components, states, relations and behaviours. Indeed in many cases, assuming a stable organization is an obvious and extremely useful simplification. Yet in complexity thinking this would rather not be the point of departure. Questions such as what is the system being investigated (i.e what are the system's boundaries), how it individuates, its possible potential for transformations etc. become significant if not critical.

An important example of thinking in this direction is found in second order cybernetics, which puts into question the boundaries between an observed system and its observer(s) (Heylighen and Joslyn, 2001; Von Foerster, 2007). The boundaries and distinctions that are formed in the course of system-observer interactions are critical to understanding such complex systems where the observer becomes an active participant in the system's dynamics. However, according to the understanding of cognition presented here, it is not merely the case that the observer is a cognitive agent that brings forth a system and therefore affects what is observed. In the course of their structural coupling *both observer and system* are transforming in a joint process of sense-making that may undergo phases of higher and lower coherency, i.e., the observer 'understands' the system and the system 'understands' the observer in the sense of behaving according to her expectations in the first case, while in the latter case the observer does not manage to make sense of the observed behaviours, interactions seem contingent and systemic boundaries are vague. Notably, in such cases, the observer's understanding becomes a significant factor within the overall coherency of the system. This is very apparent in social, economic and governance systems where actions on the side of the observer(s) informed by more or less understanding can radically change the overall dynamics of such systems.

The contribution of the extended version of enactive cognition proposed here to complexity thinking goes further than the insights of second order cybernetics. Actual reality turns out to be a matter of distinctions, boundaries, interactions across boundaries, the recurrence of patterns of such interactions, and the consequent individuation of processes and entities undergoing phases of stability and non-stability. In short, an ongoing event of cognition – sense-making sans maker. Furthermore, in the context of individuating systems, terms such as "perceptually guided action" and "sensorimotor patterns" used in 7.1.3 to describe cognition can be extended to fit the conceptual frame of individuation. An abstract sense of perception can be associated with anything capable of being affected by something else, and similarly an abstract sense of action can be associated with anything capable of affecting something else. To use the terminology developed in part one, perception and action correspond to sensibility and expression and are actualized as instances of signal-sign exchanges (see 5.2.2,5.4.2). Finally, there are possible persistently recurrent correlations between these two abstract notions that can be inferred. These correlations correspond to the reciprocal determinations intrinsic to the underlying Ideas being expressed by the system. These correspondences are sufficient to present individuating processes as perceptually guided action, that is, cognition.

Applying these notions to general systems is what broadly frames a systemic concept of cognition. Within such a frame, all systems are cognitive and systemic interactions constitute a continuum of cognitive activities at multiple levels of granularity. The advantage in relating to systems as cognitive is profound as it seamlessly introduces the formative aspect into systems thinking, incorporating the evolutionary and transformative processes of systems. This is particularly relevant to complexity thinking and to cases where there is still no clearly delineated model of a system in place.

Sense-making as a systemic activity is not reducible to the formal concept of self-organization derived from dynamic systems theory (Fontana, 1990; Heylighen and others, 2001; Lawhead, 2015). In the more conventional sense, self-organization is associated with the concept of attractors, which can be broadly understood as the (inherent) tendency of the trajectories in a given system's state space representation to converge into confined regions of that space. Such regions are called attractors as they 'attract' trajectories into them and 'resist' trajectories leaving them (e.g., objects in the gravity field of earth tend to fall downwards never upwards). The convergence of trajectories into constrained regions is actually a geometrical representation of reciprocal determination of variables as explained in 9.3.3, 9.4.1 and chapter 10. The existence of attractors is warranted by the presumption of a certain lawful dynamics that constitutes a system even in cases where the actual attractors cannot be fully analysed. What we mean by systemic cognition is a much broader and open-ended phenomenon that belongs to a more profound concept of self-organization: it is the individuation of systemic relations that eventually brings forth attractors. Ashby (1957) gives the idea a particularly simple and clear expression:

> "There is a first meaning that is simple and unobjectionable. This refers to the system that starts with its parts separate (so that the behavior of each is independent of the others' states) and whose parts then act so that they change towards forming connections of some type. Such a system is "self-organizing" in the sense that it changes from "parts separated" to "parts joined". An example is the embryo nervous system, which starts with cells having little or no effect on one another, and changes, by the growth of dendrites and formation of synapses, to one in which each part's behavior is very much affected by the other parts."

The fact of parts being joined can only be accounted for on the basis of a history of structural coupling. But if we consider an initial condition where a population of "parts" is randomly interacting, the emergence of a system must take into account processes of both integration, i.e., parts forming a persistently coherent structural coupling, and disintegration, i.e., the elimination or disappearance of certain interactions or their coherent coupling. Given enough time for processes to interact, a joint organization of a system and its milieu will arise, driven only by local bottom-up interactions (further discussed in chapters 8-9). The ongoing recurrent interactions between a system and its milieu embody the sense that the milieu makes to the system and conversely the sense that the system makes to the entirety of its milieu, which can consist of an indefinite number of other systems. The exchange of signs via interactions is the only actualization of sense and is a mark of cognition even if it seems entirely deterministic and automatic (see 5.2.2 and also 4.1.2). The reason is that the deterministic and automatic exchanges are already individuated products but a phase of individuation (co-determination) must have preceded this state of affairs and can also follow given perturbations strong enough to destabilize the established recurrent patterns of interaction.

When a system achieves autonomy by forming an operational closure among its component processes, it consequently develops a higher level of sense-making because an autonomous system can make sense for itself, as explained in 7.1.5 and 7.2 and not only for other systems (see: 5.2.2, 5.4.2). A system making sense to itself is one capable of regulating its own interactions and not only of interacting. This higher level of sense-making is also identified by Simondon (see 5.1.3.4). The major difference is that systems with an operational closure can also undergo internal individuation additional to that which is actualized in their interactions with their milieu. Furthermore, interactions among autonomous systems that together form a higher level closure open yet higher levels of sense-making, which can be considered to be cognition at the transindividual level (De Jaegher and Di Paolo, 2007) (see also chapters 11,13).

In summary, the enactive approach extended to include formative processes prior to fully individuated agents and beyond identity can be applied to general systems to the effect that the metaphysical principle of cognition is shown to be intrinsic to systems and importantly to complex dynamic systems and complexity thinking. In this sense, all systems can be said to be cognitive or cognized systems. Cognition as sense-making is realized in all systems as interactions across boundaries which bring forth actual reality.

Chapter 8

The Distributed Nature of Cognition

Chapter 7 describes systemic cognition in terms of a network of interacting processes, that is, as a distributed process that has no intrinsic centre. The parallelism found between cognition and evolution extends also to the fact that both are distributed. Notably, the notion of centre assigned to autonomous cognitive agents at various scales and domains, e.g., individual minds, evolving species. social organizations etc., is grounded in operational closure, itself a distributed structure of interdependent individual processes. This chapter explores in more detail the distributive nature of systemic cognition. The subject matter of this exploration is the formation of distinctions, boundaries and eventually individuals that in turn are instrumental to defining what distribution is. There is special significance in showing how distributed cognition in actual systems reflects their virtual multiplicity and how such multiplicity is externalized in populations of interacting individual entities.

8.1 Population Thinking and Individuation

The idea of populations and population thinking is well known from evolution theory and has roots in how the concept of biological species is conceived (DeLanda, 2013, chap. 2). The typological view of species follows the Aristotelian idea that species or natural types present a set of common essential properties shared by all the members of the species. In other words, a species is an archetype, a preexisting abstract identity that precedes all the actual instances of organisms that exemplify it. Furthermore, the variation presented by individual organisms is mostly insignificant as long as it is within the norms exacted by the species' identity. According to this view, only species can be accounted as an ontological category while the reality of individual organisms can only be grounded in the species they belong to. More generally, this view holds that the apparent variation observed in nature is rooted in a limited number of fixed forms or ideas.

Evolution theory inasmuch as it revolutionized biology had a no less profound impact on the kind of thinking originating from Platonic and Aristotelian metaphysical systems that considered identity to be primary and put variation and difference in a secondary place. Evolution theory places the highest significance on the variation presented by individual members of a species and not on the characteristics common to them. Natural selection – the driving force of evolution – is sensitive to the relative variations in individuals' capacities to survive and reproduce and is utterly blind to all those commonly shared characteristics that are identical. With evolution theory, the idea of a species as a natural type was replaced by the idea of a species as a population. This replacement has a metaphysical significance: unique individuals are the real ontological elements while a species is reduced to a status of a reification characterized by statistically derived properties. We will see shortly that there is an understanding of species that goes beyond reification however. At the moment, it is worthwhile noting that the impact of evolution theory on metaphysics is only a special case of a broader turn in modern metaphysical thinking. It clearly demonstrates that committing to unique individuals and differences as metaphysical elements naturally invites population thinking.

Population thinking is a perspective that attempts to describe and explain certain phenomena in terms of collections of unique individuals and the properties and behaviours they collectively bring forth. Which individuals belong to a population is largely contextual and depends on their specific properties, whether common or unique. Focusing on difference, two primary characteristics of populations are heterogeneity and diversity. By heterogeneity we mean a range of qualitative differences characterizing the individuals belonging to the population. By diversity we mean a range of quantitative differences, i.e., degrees of expression per specific quality, characterizing the individuals belonging to the population. For example, in the population of all organisms, there is an heterogeneity in the manner of an organism's mobility, e.g., walking, crawling, flying, swimming, jumping, being carried by winds or streams etc. and there is diversity in the speed and range of moving (possibly normalized to body size).

Population thinking becomes much more interesting when interactions among the individuals belonging to a population are considered and where heterogeneity and diversity apply also to interactions among individuals in addition to their independent properties. Once interactions are introduced three important things can happen:

1. Individuals in the population can further individuate through interactions with other individuals. Specifically, they can adapt, evolve, coordinate etc.

2. New individuals can be formed as existing individuals become coupled through recurrent interactions.

3. The population becomes a complex adaptive system possibly with emergent characteristics that makes it a distinct individual in itself (see also chapter 9).

The idea of treating whole populations as individuals is perhaps the most powerful and interesting feature of population thinking. The exemplary case of biological species as individuals formed from individual organisms is argued in detail in (Ghiselin, 1997). The individuation of a biological species according to Ghiselin is driven by natural selection and reproductive isolation (DeLanda, 2013, p. 46). Clearly, the act of reproduction performed by individual organisms is the major operation driving the individuation of the species. It is through reproduction that the individual organisms are (genetically) coupled across generations and it is through the combination of natural selection (external interactions) and reproduction (internal interactions) that phenotypic traits are inherited and become stabilized in the population, thus forming a species as an individual with observable distinctive characteristics. The exchange and reshuffling of genetic materials through generations weave together a population of individual organisms into a larger distributed body. Such bodies operate cognitively in the world thus bringing forth their own environment, albeit at scales of space and time different than those of the individual organisms that constitute them.

Unlike the view of natural types where individual organisms are merely instances of the type (species), when a biological species is considered a self-individuating entity, individual organisms play the role of organic parts within the larger whole. Also in this case the individual components form a closure but the kind of closure is more complex than the one sketched in 7.1.5 and is more similar to the fluid closures described in 7.2.4. For the individual species to exist, there is a minimal population size that must be maintained. Yet, the population size is always precarious. Individual organisms are subject to environmental pressures such as resource scarcity, disease, predators etc. and have a limited average life span. The cumulative effect of these factors is a tendency of the population size to diminish and go extinct. Against this tendency works the imperative to reproduce and bring up new generations. But this tendency must be held in check too. Overpopulation may cause the exhaustion of limited resources. The existence of a species as an autonomous individual is therefore a precarious one. The mechanisms and criteria of its continued existence are given in terms of statistical properties of the overall population, e.g., current population size, probability of reproduction, life-span of individual organisms, availability of resources, and the genetic variability of the population's gene pool. In the broader picture, it is easy and almost natural to understand inter-species dynamics in terms of interacting individuals such as in cases of predator-prey relations or various synergistic (or even symbiotic) relations such as the case of bees that facilitate the reproduction of plants, which in turn provide the bees with food.

The case of biological species as individuals can be further explored to discover that the boundaries defining individuals are generally far from being rigid or stable. Symbiotic relations, synergy, co-evolution, and cross-species exchange of genetic materials (in plants and microorganisms) are important examples of individuation processes taking place within and among populations. Beyond biology, in human populations social and cultural individuation processes can be observed where people organize into groups that maintain their collective identity via complex social interactions.

In the more general case, individuation processes taking place within populations are sensitive to processes of diversification and homogenization. Considering the combinatorial number of possibilities for individuals in a population to interact, couple and form new (compound) individuals, we become aware of the inherent tendency of heterogeneous populations to further diversify to the point of the population losing its adhesiveness and dividing into disparate sub-populations. Against this tendency to diverge there are always limiting factors at work, the first of which is environmental selection, which constrains both the heterogeneity and diversity of individuals. Interaction itself works both with and against diversification in different cases. Understanding the dynamic balance between processes operating towards further integration or disintegration of populations is of course instrumental to understanding individuation in terms of population thinking.

Depending on specific contexts and systems it is worthwhile to identify multiple strata of nested individuals where each stratum is seen as a distinct population, e.g., cells, multicellular organisms, species, ecosystems (see further 8.3) etc. Stratification into hierarchical structures, however, does not bear on the proposition that metaphysically only individuals exist. There is no hierarchy of being among individuals. Furthermore, from a metaphysical perspective, populations are the actual (externalized) counterparts of virtual multiplicities (see chapter 4) where boundaries and interactions across boundaries are the more or less distinct expressions of virtual Ideas. Well defined systems with clear boundaries and predictable patterns of behaviour correspond to distinctly expressed Ideas. Fluid boundaries and vague individual identity with less predictable behaviour, correspond to less distinctly expressed Ideas.

The following points summarize the fundamentals of population thinking:

1. Populations are collections of interacting individuals.

2. Through interactions populations become fields of ongoing individuation.

3. Populations as fields of individuation are inherently metastable.

4. Individuals can form and disintegrate, and complex nested structures with multiple levels of granularity can emerge, that is, individuals made of individuals made of individuals etc.

5. The self-maintenance of such individual entities is realized through establishing histories of recurrent patterns of interactions between the elements constituting a population.

6. Populations as individuals always exist within a dynamic balance of integrating and disintegrating tendencies (precariousness).

7. Context-dependent factors influence and regulate the overall dynamics of individuation.
8. Populations of interacting individuals, themselves treated as individuals, provide a framework that accommodates both productive processes and their products.

The theory of enactive cognition and its extension to systemic cognition fit naturally within the framework of population thinking. Boundary formation, the emergence of closures, and the bringing forth of a world through structural coupling can all be given in terms of populations of interacting individuals. We have already shown how cognition in its broadest sense is understood in terms of individuation and as such does not require the presumption of an *a priori* cognitive agency. Population thinking highlights the distributive nature of the formative processes involved in cognition and exposes their inherent complexity.

8.2 Assemblage Theory

Considering populations as fields of individuation, assemblage theory is an aspect of population thinking that focuses on the characterization of interactions and processes taking place between individuals. Individuals are metastable constructions that consist of other individuals. We term such constructions *assemblages*. Assemblages are individuals in the making that can be found at diverse states of consolidation and coherence. Contrary to the fashion systems are often represented in our models and images, assemblages are far from being the monolithic, coherent and stable entities. They are rather contingent, precarious and often hiding inner tensions, just barely containing an ongoing state of crisis as to their integrity (and identity). Assemblage is a concept first developed by Deleuze and Guattari (1987, chaps. 11-12) and further extended and clarified by DeLanda (2006). In first approximation an assemblage is a network of interacting heterogeneous individuals that brings forth an individuating yet not necessarily fully individuated entity. From a complementary perspective it is a network of interactions that brings forth distinctions and boundaries, e.g., the interactions that maintain a closure.

The elements of an assemblage, themselves individuals (or in the course of individuation), are characterized by *a*) identifying properties that define them as the individuals that they are and are subject to their own individuation, and *b*) capacities to interact – to affect and be affected by other elements. The second set of characterizations, which depends on actual interactions taking place with other elements, is by definition open-ended and non-deterministic. One cannot know in advance what will happen when two elements that never interacted before start to interact. An assemblage, being itself an individuating entity, is characterized, at least partly, by these contingent interactions internal to it[1]. An assemblage may transform radically through novel interactions, connecting to new elements or disconnecting from old ones.

Interactions can be contingent and fleeting but some of them may initiate a sequence of recurrent coordinated exchanges and form a prolonged coupling between the interacting individuals. When initially disparate individual elements happen to form a coupling and start to reciprocally determine each other's further interactions, they enter into coordinated interactivity or communication. In such cases their disparity is at least partially and temporarily resolved and they are said to form an assemblage. For assemblages, "relations do not have as their causes the properties of the [component parts] between which they are established…In fact, the reason why the properties of the whole cannot be reduced to those of its parts is that they are results not of an aggregation of the components' own properties but of the actual exercise of their capacities [to interact]." ((DeLanda, 2006, p. 11) citing Deleuze)

The difference between the concept of assemblage and the concept of system is that assemblages need not have coherency or an overall organization that defines them. In assemblages, elements can connect and disconnect serendipitously. There is no overarching pattern or principle that applies to an assemblage, making it a whole. Assemblages lack the wholeness, coherence and unity which we would expect from systems, and their characteristic structure lies on a very wide range spanning from disparate collections of randomly interacting elements to consolidated self-maintaining individuals. While the relations between the components of a system are a result of a logical necessity derived from an organization principle imposed from outside (even in the case of second order cybernetics), the relations that hold in an assemblage are contingently obligatory, that is, they derive only from the history of coupling between the interacting elements (ibid., p. 12). This coupling arises contingently because the relatively independent individuality of elements allows them to be detached from one assemblage and reattached to another without losing their integrity. Their relations are not logically imposed in any way. An interesting example of assemblages becoming systems is the case of symbiosis. When we observe mitochondria within eukaryotic cells, their systemic function as energy sources in the overall cell metabolism seems to be logically necessary. But mitochondria are symbionts; their interdependency with their host cell is not a product of design but rather of a long history of coevolution of two initially independent organisms that most probably started as an accident.

When an observer perceives something for the first time with little or no reference in previous experience, observer and observed form an assemblage. More specifically, the elements that constitute them as individuals enter into a number of parallel interactions that may be largely contingent. As some specific interactions become recurrent and coordinated (while others cease), the initial disparity of elements is being resolved and coherent relations between observer and observed are

[1]The meaning of 'internal' here is rather figurative than definitive.

established as they co-determine (individuate) each other. Such processes constitute what was described in chapter 7 as the enaction of a world, and can also be understood as the individuation of knowledge. Knowledge is established and becomes representable only when the formed assemblage reaches a threshold of coherency and stability. In most if not all cases, coherency and stability define the fidelity of knowledge. In any case, knowledge does not exist in the mind of the observer but rather as an assemblage between the observer and its milieu. It is part of a world brought forth.

Thinking in terms of assemblages is useful for further clarifying the ideas of boundary formation and fluid identities. The dynamic aspect of assemblages can be described in terms of *territorialization* and *deterritorialization* (ibid., p. 13). These two concepts qualify (respectively) to what extent a certain process contributes to the overall distinctiveness, coherency and unity of an assemblage, i.e., reinforcing the assemblage's identity, and to what extent it works against those characteristics and towards dissolution of boundaries, increase of inner tensions and disparity, i.e., disintegrating the assemblage's identity. Territorialization involves both qualitative and extensive dimensions. The extensive dimension is quite literal and involves the topological organization of the interacting individuals, e.g., how close together trees need to be in order to collectively be considered a forest. The qualitative dimension consists of those characteristics that support the unity of the assemblage e.g., homogeneity, coordination, correlation across distances etc. Note that processes can be both territorializing and deterritorializing at the same time on different aspects of the assemblage. Considering whole-parts relationships in assemblage theory, any analytic description that highlights the parts over the whole can be said to deterritorialize the whole while territorializing the parts. In contrast, synthetic descriptions that highlight the whole while blurring the individual boundaries of the parts can be said to territorialize the whole while deterritorializing the components. Here we can see the role observers can play in the formative processes of assemblage and individuation. By forming observations, representations and descriptions, observers catalyze territorialization and deterritorialization processes in the course of individuation. Evidently such interventions are reflexive in the sense that they affect the individuation of the observer as well.

The individual components of assemblages play two major kinds of role in their interactions termed *material* and *expressive* (ibid., p. 12). To understand these categorical roles, consider a DNA molecule as an assemblage made of a chain of nucleotides – the assemblage's components. Each nucleotide is itself a medium size molecule capable of chemically attaching to other molecules of its kind. In DNA, there are four different kinds of nucleotides uniquely paired to each other forming the four unique components of a double stranded helix structure. These pairs can attach to each other in arbitrary and equiprobable order to form arbitrarily long DNA molecules. To this effect, the nucleotides play a material role. However, this is not why DNA molecules are interesting. For certain other molecular assemblages the individual nucleotides and their order of attachment express a code that is read and transcribed via complex molecular mechanisms into various RNA and protein structures that carry out catalytic and regulative functions within the living cell. In their interactions with the transcription mechanisms, the nucleotides play an expressive role rather than a material one, that is, they *signify* something for somebody other than themselves. In summary, material interactions are constitutive to the assemblage's structure, and expressive interactions are significant in how the assemblage affects or is affected by other individuals.

The correspondence between the material and expressive aspects of assemblages introduces a new level of organization (and complexity) where the structure of an assemblage defines its significance in a broader context. To continue with the DNA example, the unique expressive roles of certain nucleotide chains for other cellular mechanisms brings forth a new heterogeneous population of individual functional units – genes that code for proteins and non-coding control sequences that regulate the complex processes of gene transcription. Both kinds of unit display a virtually indefinite wealth of expression and hold complex relations among them and other components of the cellular machinery.

DNA molecules are but one example of a family of assemblages called *strings*. Strings are the simplest form of assemblage where each element connects to only one or two other elements forming linear chains of elements. Following the rationale discussed in 8.6.1 ahead, even such simple structures are capable of displaying very rich complex expressions. Language and linguistic constructs is another such example. In both cases a variety of material components that can be arbitrarily chained (e.g., nucleotides, sounds) together with a set of constraints on their material constructions[2] give rise to an entirely new dimension of signs and signifying interactions among individuals, that is, the dimension of symbolic expressions and symbolic interactions.

The expressive role played by symbols can be associated with the concept of sign discussed in 4.1.2 and with signal-sign systems discussed in 5.2.2. In the DNA example the chemical interactions are the signals that encode discrete signs in the context of genetic transcription mechanisms. Signs (also later referred to as *codes*) always hide a multiplicity of signals that materially constitute them. In the terminology of assemblage theory, signs are territorializations of their material counterparts. That is, the sign is the expression of all the material configurations that belong to a certain territory defined by its singular expression. While from the material perspective one will observe a variety of different assemblages, from the expressive perspective one will observe a homogeneous territory where whatever belongs to the territory expresses one and the same sign. In human spoken language there are many ways to articulate a word. Ways that differ, in accent, intonation, pitch, rhythm and other parameters specific to the speaker. As long as these variables are within a certain

[2] E.g., in language, these are the syntactic rules that regulate the construction of linguistic utterances.

territory they produce the same sign. Yet, even minor deviations outside the territory may render the utterance incomprehensible as is often the case with non-native speakers.

Populations of signs present combinatorial productivity: by merely combining signs into strings, an indefinite number of structures with unique expressions can be produced. The production of expressions via combinations of signs or codes is called in assemblage theory *coding* (DeLanda, 2006, pp. 14-15). The power of coding is the formalization of expression. In human linguistic interactions, for example, we encode fluid experiences into much more concrete linguistic expressions, that is, symbolic representations that consolidate our experiences, make them memorable, recognizable, communicable and manipulable in ways that are impossible to exercise with the raw materiality of experience. Coding, as is apparent from the example, may fulfil a role parallel to territorialization when it homogenizes the expression of diverse material manifestations. Coding, like territorialization, has counterpart kinds of process termed *decoding* that deterritorialize the homogeneous expressions achieved by coding. For example, genotypes based on genes as signs encode phenotypic expressions of life forms. This system of coding is what enables not only the inheritance of genetic information from generation to generation but also the genetic variation achieved either by discrete mutations (errors in the reproduction of the code) or the mechanism of recombination (the reshuffling of genes between two genomes). Yet actualized phenotypes, when interacting in their environment, undergo processes of adaptation. Adaptation, while not affecting the underlying genetic code that encodes the phenotype may yield a variety of phenotypic expressions that correspond to exactly the same genetic code (e.g., by means of epigenetic effects). Adaptation therefore is said to be a process of decoding that deterritorializes the discrete correspondence between codes and their expression[3].

The concepts and processes explored in chapter 7 can all be described in terms of assemblage theory, highlighting their distributed nature. Autonomous agents are territorialized assemblages. The interacting processes correspond to their material aspect and the closure being maintained along with the world it brings forth correspond to their expressive aspect. While maintaining autonomy, they undergo structural transformations, that is, transformations of their material aspect while their expressive aspect remains unchanged (as long as the transformation is within their viability set) though it has a dynamism that depends on the milieu. The case of fluid identities can be described in similar terms. While the expressive aspect of fully individuated autonomous agents maintains stability, a fluid identity is an assemblage undergoing both material and expressive transformations. It is much less territorialized and distinct and its expression is metastable. Identity is always given in terms of the expressive aspect of individuals. Yet the mechanisms that are instrumental to the maintenance of identity are material mechanisms. We are now in a position

[3]This is a considerably simplified rendering of the concept of coding compared to its development in (Deleuze and Guattari, 1987).

to account for how complex cognitive structures arise from simpler ones and how different strata of complex individuals are related through interactions.

8.3 The Stratification of Cognition

From a metaphysical point of view individuals at whatever level of complexity have the same status. Yet in terms of populations it is worth noticing processes of stratification that give rise to structural hierarchies of individuals. For structural hierarchies to emerge we need to consider individuation events at the scale of populations (see 8.6.3 ahead). Considering a large and heterogeneous population P_0 of interacting individuals, stratification happens if recurrent interactions in P_0 bring forth a new population P_1 of relatively stable compound individuals which is itself large and heterogeneous enough to provide circumstances for the further emergence of populations $P_2, P_3, \ldots, P_n$ in the same manner (see also subsection 4.2 in (Weinbaum and Veitas, 2016b) rendered in chapter 12).

Processes of stratification are probabilistic in nature and have both bottom-up and top-down aspects. The individual elements of populations have rates of production and disintegration that depend on the frequency of interactions with territorializing and deterritorializing effects respectively. For multiple strata to emerge, individual elements need to be stable enough to allow high enough probability of interaction with other elements. The probability of interaction among elements depends in turn on their relative frequencies in the population and their accessibility to interact. Further stratification of a population therefore depends in general on the interplay among these probabilistic parameters, which together constitute bottom-up regulative influences.

As compound individuals form in large enough numbers, they have the effect of constraining the interactions of their components. Such constraints can be understood as additional determinations in the course of the components' process of individuation, further consolidating their identity (i.e., territorialization). In the example of nucleotides and DNA, the whole environment of the cell relates to nucleotides as signs in the machinery of producing proteins and regulating cell activities. In the context of cells, the rich repertoire of chemical interactions that nucleotides are capable of is significantly narrowed down to interactions relevant to their cellular function.

In the case of general populations and the compound individuals forming within them, clearly, different individuals are formed with variations in stability and frequency of occurrence. Such variations have a top-down influence on the productive processes taking place in a population. To see why, consider a case where the majority of elements in a producing population become bound to a specific set of compound individuals. They lose their independent individuality (i.e., they undergo deterritorialization) and dissolve into new individuals that are the elements of a population on a new stratum. In such a case, the production of other compound individuals that are less easy to produce, and initially were less frequent, become even less probable because most of the elements of this population (the material resources) have already become bound to other constructs. Consequently, the probability distribution of formative processes affects the population in such a way that certain constructs become much more probable while others become much less. In a broader view this would mean that certain trajectories of future development of higher strata are being eliminated while other trajectories are reinforced. This is how a stratum can exert selective influences, both on lower and higher strata. Vertical influences both bottom-up and top-down can occur in parallel across multiple strata so that individuation may and does occur at multiple scales, yet not necessarily at equal rates.

Comparing two strata of individuals – the producing stratum and the produced one – the interactions among compound individuals consolidated at the produced stratum are both more complex and more constrained than the interactions among individuals possible at the lower producing stratum. The emergence of a new stratum therefore involves constraints and territorializations not only of individuals but of their interactions as well. For example, multicellular organisms interact with each other as individuals and not as conglomerations of cells, species interact as co-evolving entities and not as specific animals, social organizations interact as individuals and not as the collections of humans and systems that embody them etc. What can be observed here is that once a new stratum emerges, the individuals that populate it engage in interactions that territorialize each other. Such engagements also have effects on individuation processes in the substratum (top-down influence) and the superstratum (bottom-up influence).

The idea of systemic cognition suggests that individuals have an intrinsic granularity, that is, an intrinsic substratum of elements and interactions that constitute them and in which the history of the elements' structural coupling is expressed. Stratification is a process of systemic cognition which derives from the individuals of the substratum and their capacities for interaction. No cognitive structure is brought forth in isolation, it is always a whole population of individuated structures – a new stratum that is brought forth. This is a distributed process with no centre and no *a priori* guiding principle. Yet, not anything goes; certain paths of expression are selected actualized and constrain further evolution while other paths remain only virtual.

In all such cases reductionist descriptions and explanations can be given by observers which are external to the mentioned individuals and their domain of interactions. But such descriptions and explanations are only possible and valid on account of the assemblages formed between individual observers and the observed individuals. When examining an individual, observers need to identify which are the elements and interactions relevant to its individuation (i.e., its intrinsic granularity) but additionally consider the elements and interactions relevant to the reciprocal individuation taking place in the course of observation itself. For example, to say that a living organism is made of atoms is a legitimate statement of fact but does not expose anything interesting about the organism's individuation. The stratum where the phenomenon individuates (e.g., cells) and the stratum whose elements are used to ground the description (atoms in this case) are too far apart. An organism individuates from a lump of identical cells originating from a single cell in a developmental milieu (egg, womb, or a cell membrane in case of unicellular organisms), an individual species individuates in an evolutionary milieu (ecosystem), social organizations individuate in a social milieu etc. As observers we can always identify a different stratum of interaction as interesting or relevant but these identifications are observer-dependent objectifications and not objective in any absolute sense. In comparison, the intrinsic granularity of individuals is a consequence of a history of coupling. It is not in any way more objective or logically necessary but rather reflects a contingent development with intrinsic significance.

8.4 Coding, Representation and Stratification

Following the ideas developed in 8.2-8.3, a coding system is a language-like formal system with a finite set of symbols (signs) and a finite set of syntactic rules that specify how compound individuals are produced, that is, how expression is generated from structure in assemblages of elements. Coding systems are mechanisms of combinatorial productivity; they produce diverse expressions by forming combinations of elements according to their given rules. Such systems are themselves a product of earlier individuation and normally represent a stratum of individual elements and their interactions. They constitute a ground that facilitates further individuation. In the course of stratification, a few such coding systems may emerge one on the top of the other, each with its own elements and syntax. It is true that due to the finite sets of elements and interaction rules there are inherent limits to the scope of what can be possibly described with any such coding system. Nevertheless, and as already discussed above, these powerful mechanisms are capable of spawning rich, heterogeneous and virtually inexhaustible populations of dynamically interacting individual entities.

Examples of coding systems are many. The set of atoms and the rules governing chemical reactions, DNA sequences that encode proteins capable of various metabolic functions, all spoken languages that produce meaningful significations by combining vocal utterances or written symbols, Turing machines that perform general computations encoded by a sequence of input symbols, etc. While the productive power and richness of specific coding systems cannot be overstated, it is the power of general languages capable of recursively producing other coding systems that is responsible for our capacity to understand the world. Observers conjure up coding systems to represent their observations and manipulate such systems to produce explanations. The individuation of such coding systems stands at the basis of acquiring knowledge. It reflects the individuation of knowledge in the course of interactions between an observer and the observed phenomenon. It is how the individuality of both observer and observed is consolidated in observation.

The concept of representation and thought as representation can be understood in terms of coding systems. A thought (in the broad sense we mean in this work) is supported in as far as it can be described within at least one coding system. The whole idea of support is rooted in the existence of a finite coding system. Certain thoughts can be given finite descriptions. Other thoughts can only be given infinite descriptions but still with finite sets of elements and combinatorial rules. Such thoughts, though not having a complete description, may have arbitrarily close approximations by progressively producing longer finite descriptions. But there are those thoughts that are entirely unsupported because no coding mechanism exists for them as yet. Perhaps the most interesting case is the individuation of coding mechanisms themselves. What is special about such mechanisms is a finite and (relatively) stable set of elements and rules that gives rise to indefinite proliferation of expressions. The individuation of such mechanisms involves therefore the reduction from infinite to finite of the number of involved individuals and their possible interactions. Both reductions have to do with limiting difference, which is synonymous with limiting determinability (see 4.1.1). Additionally, the requirement of stability implies that elements do not lose their individuality in the course of their interactions (e.g., chemical reactions involve only an atom's electrons while its nucleus remains intact).

A fascinating point is that given such conditions, the heterogeneity of further individuations seems to have an inherent tendency to self-limit and consequently to form higher strata. Moreover, such tendency is conjectured to be universal because it does not depend on the nature of elements or interactions involved. To gain an intuition of this self-limiting nature, assume we start with some *a priori* given stratum of elements with its associated coding system and try to figure out what individuations might ensue. With a coding system at hand, it is possible to enumerate for every individual describable with such a system the list of all descriptions that bring it forth, from the most compact descriptions to the indefinitely long and most complicated descriptions. Following the line of thinking developed by Solomonoff (1964a) regarding the problem of inference under the condition of no prior knowledge, an interesting observation can be made regarding individuation. If we compare different individuals looking only at their lists of possible descriptions, two major distinctive features are apparent: *a*) the length of the most compact description of any individual varies among individuals, and *b*) the total number of possible descriptions *of any length*, i.e., the number of ways any single individual can be produced by a description shorter or equal to a given length varies among individuals. These distinctive features exist irrespective of the particular nature of individuals and their interactions. Notice also that the longer a description becomes, the more combinatorial possibilities there are to produce individuals, and consequently there are also potentially more combinatorial possibilities to generate any specific individual.

Consider a random description of a given length of N or less symbols and try to estimate what individuals it is likely to generate. Intuitively, and without entering the more rigorous mathematical considerations involved, individuals of shorter descriptions will be more likely to be generated than individuals of longer descriptions (individuals of minimal description longer than N will not be generated at all). Furthermore, individuals with comparatively more different descriptions shorter than N, will be more likely to be generated than those individuals with only a few descriptions. It follows that a population of randomly generated individuals will not be uniformly distributed across all possibilities. We will probably find many more individuals which are structurally simple or that can be generated in numerous ways than other individuals that are more complex and uniquely structured. From the very same consideration, interactions among individuals will not be uniformly distributed among all possibilities. Interactions (and therefore further determinations) among individuals that are more likely to emerge will also be more likely to take place and influence further individuation. Certain trajectories of development are therefore *a priori* more probable then others. All other complications, i.e., the progress of determinations depending on the particular nature of interactions, take effect on the basis of such prior bias. These non-uniform likelihoods seem to definitely point towards a universal self-limiting tendency of individuation once we assume an initial set of elements.

The question remains, however, whether we can infer the same kind of reasoning to cases where an *a priori* given coding system does not exist. Without a coding system it is impossible to assign any notion of differential likelihood to different individuals and their interactions. Our intuition regarding the difference in likelihood between simple versus more complex structures has no basis here since the very notion of simple and complex is derived from representing complex structures in terms of simple elements and relations. Therefore there is nothing one can say about the likelihood of emergence of an unsupported thought and specifically of an unsupported coding mechanism. Only when such a mechanism emerges will it have the tendency to further stratify and bring forth further coding systems[4].

To summarize the last three sections, assemblage theory and the stratified articulation of individual entities in populations provide a framework to describe cognitive and evolutionary formative processes of general systems. This descriptive framework is not confined to any specific discipline or category of phenomena and can easily be deployed across multiple disciplines and categories. The following sections address some formal aspects of the ideas presented thus far.

[4]As a side note, the discussion of coding systems highlights again the significant contrast between the image of thought and thought sans image. The belief that the world is representable in principle is equivalent to the belief that there is an *a priori* given universal coding system that underlies all knowledge.

8.5 Individuation and Information Integration

8.5.1 Information Integration

The qualitative concepts discussed in 8.2-8.3 can receive a quantitative perspective using information theory and specifically the concept of information integration developed by Tononi et al. in the context of computational neuroscience (Tononi, 2008; Tononi, 2004, 2012; Tononi et al., 1998). The idea behind information integration is that given a population of interacting processes, and a subset of processes within the population, it is possible to quantify to what degree the processes within the subset are interactive and compare it to the degree of interactivity between the subset as a whole and the rest of the population. Such measures provide an approximate analogue to the degree of individuation and distinctiveness of subsets of processes in the population and possibly can be used to reflect stratification and the granularity of emergent strata. These might prove relevant in applying the ideas developed in this work in specific contexts.

It was argued earlier that individuation cannot be formalized or mathematically modelled. The concepts discussed here are therefore simplified approximations based on the assumption that once we consider a population of already individuated elements which, together with their distribution in the population, are relatively stable, we can express their properties and interactive capacities in terms of information theory. In such cases, boundary formation and the individuation of compound entities, such as the ones discussed in chapter 7, can be approximated as clustering processes. In general, individuals are not clusters because what holds them together are interactions and not the common properties of their elements. But as the behaviours of elements become correlated and they form more or less stable interactive networks, there is an aspect of clustering to individuation. Though this simplification loses important subtleties involved in individuation, it is worth mentioning because it provides a clear and more concrete perspective to what is going on in processes of individuation and systemic cognition.

Consider a set X with X_i elements where each element is an individual process with a repertoire of states S and with a probability distribution $P_{X_i}(S)$. The entropy of any element X_i is equivalent to the amount $H(X_i)$ (in bits) of uncertainty being eliminated by the determination of the state of X_i which is also the information that X_i contains. The entropy of any X_i is given by the following formula (see: (Shannon, 2001)):

$$H(X_i) = -\sum_{j=1}^{n} P_{X_i}(S = s_j) log_2 P_{X_i}(S = s_j) \tag{8.1}$$

If the elements of X are non-interacting, their states are produced independently from each other and there is nothing we can learn about the state of X_j from knowing X_i. But if on the other hand they do interact, they share some information between them which is called *mutual information* and is given by the following formula:

$$MI(X_i, X_j) = H(X_i) - H(X_i|X_j) = H(X_j) - H(X_j|X_i) = \\ = H(X_i) + H(X_j) - H(X_i, X_j) \quad (8.2)$$

The term $H(X_i|X_j)$ is to be understood as the information remaining unknown about X_i if X_j is given, or what X_j is not telling about X_i. If X_i and X_j are independent, $H(X_i, X_j) = H(X_i) + H(X_j)$ and then $MI(X_i, X_j)$ would be 0. The mutual information would be maximum in the case that the state of one agent is fully determined by the other. In this case the mutual information will be equal to $H(X_i) = H(X_j)$ (the elements carry exactly the same information).

In a simplified model describing the interactions among the elements of X we can arbitrarily divide X into two complementary subsets A and B. We define the *effective information* (EI) as how A maximally affects B by assigning to A maximum entropy, that is, the elements of A can independently take any value, and express the effect on the entropy of B:

$$EI(A \to B) = MI(A^{H_{max}}, B) \quad (8.3)$$

If the states of A are randomized to produce maximum entropy[5], they cannot be affected by the states of elements in B so the equation expresses only the effects of A on B. Similarly in the other direction:

$$EI(B \to A) = MI(B^{H_{max}}, A) \quad (8.4)$$

Combining the equations 8.3 and 8.4, we get the reciprocal effects between A and B:

$$EI(A \longleftrightarrow B) = MI(A^{H_{max}}, B) + MI(B^{H_{max}}, A) \quad (8.5)$$

These effects depend of course on the actual interactions going on and are bound by the maximum entropy either of the subsets can produce:

$$EI_{max}(A \longleftrightarrow B) = 2\min(H(A^{H_{max}}), H(B^{H_{max}})) \quad (8.6)$$

Returning to the set X, the idea of information integration of the set expresses the effects of any arbitrary subset $A \subset X$ on the complementary subset $X \setminus A$. If X can be divided so that $EI(A \longleftrightarrow X \setminus A) = 0$, this would mean that there are at least two subsets in X independent of each other. Following this reasoning, the level of integration of the overall set X will be only as high as the minimal effective information that can be found for any bipartition $(A, X \setminus A)$. But in order to compare all possible bipartitions of X, we need also to consider the different sizes of the

[5] In such a case the entropy of A is the sum of the entropies of the elements $X_i \in A$ and the entropy of B can either be analysed if the whole structure is known or empirically sampled.

subsets. To do this, the compared effective information needs to be normalized by $EI_{max}(A \longleftrightarrow X \setminus A)$. Let $(A_{mib}, X \setminus A_{mib})$ (minimal information bipartition) be a bipartition that minimizes the normalized information integration (there can be a few):

$$A_{mib} := \arg\min_{A \subset X} \frac{EI(A \longleftrightarrow X \setminus A)}{EI_{max}(A \longleftrightarrow X \setminus A)} \tag{8.7}$$

Thus we reach the following expression of information integration $\Phi(X)$:

$$\Phi(X) = EI(A_{mib} \longleftrightarrow X \setminus A_{mib}) \tag{8.8}$$

The function $\Phi(X)$ can be interpreted as the minimal amount of information exchanges involved in interactions in X. When $\Phi(X) = 0$ it means that X is divisible into at least two non-interacting subsets. When $\Phi(X) \approx EI_{max}(A_{mib} \longleftrightarrow X \setminus A_{mib})$, it means that approximately every element in X maximally affects and is being affected by all other elements. Using Φ, Tononi (2004) defines structures called *complexes*. A complex is any subset $A \subset X$ for which there is no other subset $A^{'} \subseteq X$, such that: *a*) $A \subset A^{'}$, and *b*) $\Phi(A^{'}) > \Phi(A)$. The rationale behind this definition is that if $A^{'}$ is with the greater Φ it means that A is only part of a larger and more integrated network of interactions.

The idea of Φ and complexes is quite interesting. Remarkably, Tononi argues that consciousness corresponds to the capacity of neural structures in the brain to integrate information and particularly that conscious states correspond to complexes (ibid., p. 6). Here we apply the idea of information integration in the much wider context of individuation and systemic cognition leaving aside for now its possible correspondence with phenomenological states. The dynamism of individuation can be reflected in $\Phi(X)$ and in the structure of complexes once we allow that interactions within assemblages are not fixed. As discussed in 8.2, elements can join and leave an assemblage as interactions appear and disappear. If X in the mathematical developments above is an assemblage evolving in both time and space (i.e., where its elements are embodied; this need not be necessarily physical space), then $\Phi(X)$ also evolves in time and space and the structure of complexes is to be considered as dynamic.

8.5.2 Intrinsic Granularity

In our case, the fact that the information integration of a complex is larger than the integration of any subset of elements contained in it can be interpreted as meaning that a complex is irreducible to a system of components other than the elements $X_i \in X$. For these elements, Φ is not defined because we do not consider their internal structure that consists of elements of a yet lower stratum. Any attempt to divide a complex to smaller distinctly integrated modules other than X_i would fail because any such module can be shown to be more interactive across its boundary than internally. From a perspective of a population P, given by the set of its assumed individuated elements, the set of complexes in P defines the next stratum (higher in the hierarchy) of elements, which are then considered as the components of structures at that higher stratum. This would be of course a simplified view since complexes can possibly share some elements and therefore produce assemblages which are irreducible yet are not complexes. Nevertheless, a certain approximate conception of intrinsic granularity and consequently intrinsic modularity of structure across strata can be based on complexes. By intrinsic here we mean that complexes are defined only on the basis of interactions internal to them and irrespective of other interactions they might have with elements external to them. Worth noting is the additional dimension of complexity having to do with the dynamic nature of complexes (see also 11.3 for illustrations and further discussion).

Given our interest in the individuation of general systems, the existence of intrinsic modularity, even an approximate one, is quite powerful. Simon (1962) argues that modularity in systems substantially increases the probability of emergence of complex structures out of simpler ones. Applying Simon's argument to individuation in general means that the individuation of complex structures is a natural tendency once the emergence of complexes can be established with good enough approximation. This tendency need not be supported by further specific conditions or circumstances. It is not entirely clear, however, under which general assumptions interactions will invariably bring forth (with good enough approximation) populations of complexes. The hypothesis of intrinsic granularity supporting an intrinsic tendency towards the individuation of complex structures, though plausible, remains a topic for further research.

8.5.3 Boundaries and Distinctiveness

Considering the relations between X and a larger population P, it would be interesting to express the distinctiveness of X in its milieu using information theoretic terms. If X is a complex, there is no subset $X^{'} \subseteq P$ so that $X \subset X^{'}$ and $\Phi(X^{'}) > \Phi(X)$, meaning specifically that $\Phi(X) \geq \Phi(P)$. We can then define the milieu of X as $Mil_X := P \setminus X$ and develop expressions for the interactions of X and Mil_X. The effective information from the milieu to the complex X, or the extent the milieu affects X is given by:

$$EI(Mil_X \to X) = MI(Mil_X^{H_{max}}, X) \leq H(X) \tag{8.9}$$

Assuming that the milieu is much larger than X, and also that X is a complex, it is plausible also to assume that $Mil_X^{H_{max}} \gg H(X)$ and therefore the effective information is bound by $H(X)$. This means that the capacity of the milieu to affect X is much larger than the capacity of X to be affected (without changing or disintegrating). Since $\Phi(X)$ expresses the overall impact of the interactions of X with itself, the effective information of the milieu is approximated by:

$$EI(Mil_X \to X) \approx H(X) - \Phi(X) \tag{8.10}$$

A measure of distinctiveness $Dis(X)$ can be expressed as the ratio between the internal and external influences:

$$Dis(X) = \frac{\Phi(X)}{EI(Mil_X \to X)} \approx \frac{\Phi(X)}{H(X) - \Phi(X)} \tag{8.11}$$

$Dis(X) \to \infty$ indicates a distinct assemblage which is barely affected by its environment and therefore mostly self-individuating. $Dis(X) \to 0$, on the other hand, indicates a barely integrated structure where most of its dynamics is driven by external interactions.

When it comes to the overall interaction between an individuated complex and its milieu, a first approximation would be the effective information $EI(Mil_X \longleftrightarrow X)$. Admittedly this expression is too gross, not taking into account the moment to moment dynamism of cognitive activity in the course of individuation. A concept that does take into consideration the history of interaction is *transfer entropy* (Schreiber, 2000). Consider two random processes A, B with respective entropies $H(A), H(B)$ that produce a time series of state changes $A_t, B_t, t \in N$. Consider that both A_t, B_t depend on a history of L time intervals from the current moment. The transfer entropy $T_{A \to B}$ is defined as follows:

$$T_{A \to B} := H(B_t | B_{t-1:t-L}) - H(B_t | B_{t-1:t-L}, A_{t-1:t-L}) \tag{8.12}$$

Where $H(B_t|B_{t-1:t-L})$ is the uncertainty about B_t given its history and $H(B_t|B_{t-1:t-L}, A_{t-1:t-L})$ is the uncertainty about B_t given the histories of both A_t and B_t. In other words, it is the uncertainty about B eliminated by knowing A. Notice that as A, B evolve in time their probability distributions might change and so too the transfer entropy.

We can now write more explicit expressions for the information transferred from the milieu to X through its perturbations of X. This can be qualitatively interpreted as the information gained by an agent X's perception:

$$T_{Mil_X \to X} = H(X_t | X_{t-1:t-L}) - H(X_t | X_{t-1:t-L}, Mil_{X_{t-1:t-L}}) \tag{8.13}$$

Similarly, the information transferred from X to its milieu and loosely interpreted as the information transferred to the milieu by actions is given by:

$$T_{X \to Mil_X} = \\ = H(Mil_{Xt} | Mil_{X_{t-1:t-L}}) - H(Mil_{X_t} | Mil_{X_{t-1:t-L}}, X_{t-1:t-L}) \tag{8.14}$$

The combination of equations 8.13-8.14 shows that some of the information transferred from X to its milieu by its actions is recurrently fed back to X *via its milieu* as perceptions. The information fed back corresponds to enactive cognition as the history of structural coupling between X and its milieu. These formulas are not necessarily useful as they are but they nevertheless express the coupling between an agent and its milieu even prior to the emergence of closure. Before any individuation takes place the information being transferred would simply be noise. But in the course of boundary formation, $T_{Mil_X \to X}$ and $T_{X \to Mil_X}$ will gradually become correlated as the agent-milieu interactions progressively bring forth a world where actions and perceptions are indeed correlated. Here also the meaning of $\Phi(X)$ becomes clearer: the more information is integrated in X, the sharper the filter it becomes for the information transferred through it. In other words, the higher the integration, the more the structure of X contributes to the correlation between its perceptions and actions. But as $\Phi(X)$ approaches closer to $H(X)$, $EI(Mil_X \to X)$ diminishes to 0 and X, accordingly, decouples from its milieu.

8.6 Contingency and Innovation

In the discussion up to this point, there is a critical role to random processes in bringing forth actual order from non-order and sense from non-sense. This is exactly the idea behind the metaphysical principle of self-organization discussed throughout chapters 3, 5 and 6: there is in existence an inherent tendency to organize spontaneously. This stands in sharp contrast to the second law of thermodynamics which states that systems will tend to increase their entropy till they reach a state of maximum entropy that in information theoretic terms means that all states are equiprobable, i.e., no organization. Still, as already mentioned, the very notion of maximum entropy must assume a closed system, which in the terms developed in the first part of the thesis would mean that difference is bound. We see no reason good enough to warrant such an assumption on a universal scale. The development of this thesis explores the idea of open-ended systems and unbound difference and highlights the emergence of the significant and sensible out of the insignificant and indifferent. In whatever way we may choose to term it, thought, cognition, evolution or self-organization, it is far from intuitive how disorder brings forth order. This is why till the advent of modern evolution theory, the common understanding of order needed a higher, godly or esoteric first principle as an explanatory anchor to account for all the order apparent in existence. Yet even today the debate is going on as to whether the combined effects of random contingent change and natural selection are sufficient to account for the emergence of form in all dimensions, and here, natural selection is meant in the broad sense that exceeds its biological context (Campbell, 1997; Dennett, 1995). Wagner (2011, p. 2) clearly highlights the problem in the biological context, which seems to apply universally:

> "While Darwin's theory rightly emphasized the role of natural selection in preserving useful variation, it left untouched the question how new and useful variation originated . As the geneticist Hugo de Vries put it in 1904 [...], "Natural selection may explain the survival of the fittest, but it cannot explain the arrival of the fittest." This question about the origins of new things is still fundamentally unanswered. What is it about life that allows innovation through random changes in its parts? This ability becomes especially striking when we contrast it with the properties of most man-made, engineered systems. Would random changes in a typical complex technological system, say, a computer or an airplane, be a sensible recipe to improve the system? Hardly."

To rephrase this question in the much broader sense of the emergence of general systems and forms would be to ask what it is about existence that allows innovation – the emergence of new order and significance through the individuation of actual entities? In other words, how do stable forms and recurrent behaviours arise from unbound differences? One useful way to think about it is what DeLanda (1998, pp. 12-13) calls "combinatorial productivity":

> "A crucial question regarding open-ended evolution is the nature of these "spaces of chemical (or biological, or social) combinations". It is becoming increasingly clear that a crucial ingredient for the emergence of innovation at any level of reality is the "combinatorial productivity" of the elements at the respective sub-level, that is, at the level of the components of the structures in question. [...] The point here is that a key ingredient for combinatorial richness, and hence, for an essentially open future, is heterogeneity of components. Another key element are processes which allow heterogeneous elements to come together, that is, processes which allow the articulation of the diverse as such."

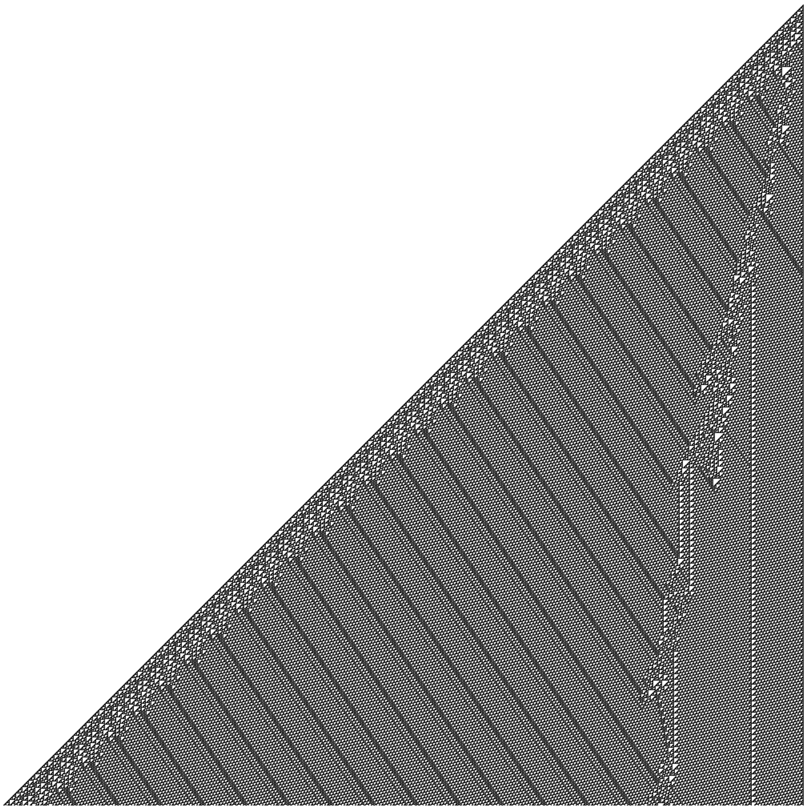
In this chapter we propose population thinking and assemblage theory as a framework of articulating individuation – the progressive determination of actual individuals in terms of distributed processes that manifest combinatorial productivity. At the most fundamental level it is the encounter between elements affecting and being affected by each other in the course of their interactions that is the abstract mechanism driving determination, or as Gregory Bateson phrased it: "differences that make a difference". In sections 8.3- 8.5 we draw how given populations of interacting heterogeneous elements may spontaneously bring forth more complex elements and recursively stratify, eventually producing open-ended innovation even without guidance. In order to gain further credibility this proposition needs further examination of a number of its problematic aspects.

8.6.1 Unbound Expression

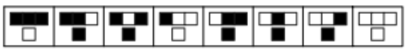
From the metaphysical perspective developed in part one, difference is an unbound source of Ideas. But Ideas are considered only on account of having individual actual expressions (see 4.2.3). As suggested above, expression is a combinatorial process of "articulation of the diverse as such". The question that remains is: are there no bounds to expression? Is actual existence infinitely creative? Seemingly the question is readily resolved by considering the exploding number of combinations possible within populations of elements, capable of giving rise to unique individuals. But individuality alone does not translate to significance. All the grains of sand on the banks of the river Styx are unique individuals, but theirs is not a significant individuality because they all express one virtual Idea. They are merely cases of repetition reflecting the internal multiplicity of the Idea. The real question is therefore about innovation – the actual expression of new Ideas never expressed before.

This can be put more precisely in terms of the relations between the material and expressive aspects of assemblages. The material aspect of an assemblage (see 8.2) corresponds to the kinds of element and their interactions that constitute the assemblage as individuating structure (we will use the term structure from here on to indicate the material aspect). Combinatorial productivity is structural. It is the unbound heterogeneity of structures produced by combining together different elements, e.g., as words are combined into texts or atoms into molecules. The expressive aspect is the sense an assemblage makes as a whole to all other individuals in its milieu. It is how it affects them and actually forces them to sense by merely existing. Sense, therefore, is multiple because it is inherently a product of multiple perspectives, that is, of an indefinite number of perspectives of all other individuals. As the expression of an assemblage depends on both its structure and its milieu, and as we are specifically interested in the relations between the structural and expressive aspects of assemblages, we will neutralize the contribution of the milieu to the richness of expression by assuming for this discussion that it remains constant. Now we can ask whether it is the case that unbound heterogeneity of structure implies unbound richness of innovative expression. We cannot assume that the relation of structure to expression is isomorphic. A single structure may have multiple expressions depending on the other individuals it interacts with. But it is also the case that different structures may have the same expression. We cannot therefore trivially derive the unboundedness of expression from unbounded combinatorial productivity. Grains of sand are a point in case.

Expression is the production of structurally dependent behaviour. An assemblage produces affects (acting upon its milieu) in response to perturbations it undergoes and in accordance with rules embedded in its structure. These rules originate from the nature of the elements that constitute the assemblage and their respective interactions (remarkably, structure itself is a manifestation of expressions at the lower stratum of the interacting elements that constitute it). One way to study the relation between expression and structure is to regard expression as an outcome of a computation. The computation is carried out by the structure as a computing element actively operating the rules intrinsic to it (e.g., for physical structures these would be the laws of physics, for economical structures these would be the rules of the market etc.), and where the ongoing perturbations are the inputs to the computation being interpreted in terms of the rules embedded in the structure. This is of course a simplifying metaphor as it represents complex relations in terms of discrete symbolic manipulations but it is sufficient for the point to be made here.



(a)



(b)

Figure 8.1: (a) The first 1000 steps of running rule 110 cellular automaton displaying both regular and irregular patterns of behaviour (enlarge for more detail). (b) A graphic depiction of rule 110 cellular automaton. At each step, each cell in the upper row is converted into the cell in the lower row depending on its current content and the content of its two adjacent neighbours. The number 110 encodes one of the 256 possibilities of conversion possible for such configuration. (Reproduced from: (Wolfram, 2002, p. 32))

Wolfram (2002) develops a hypothesis – the principle of computational equivalence, that bears on our case (particularly chapter 12). The principle claims that "almost all processes that are not obviously simple can be viewed as computations of equivalent sophistication." (ibid., p. 716). By "obviously simple" Wolfram means any process for which a compressed description can be readily found (e.g., for the process generating the members of Fibonacci series, the formula for the n-th member is obviously a simple replacement of recursively computing the n-th element). We will not enter into the intricacies involved but in simple terms the principle asserts that in computational terms very simple computing processes can and do perform computations as complex and as sophisticated as arbitrarily complex computing processes. Figure 8.1 depicts a representative example: rule 110 cellular automaton is a very simple structure that displays a complex pattern of behaviour which is both regular and irregular. This behaviour seems never to converge into a regular pattern nor to diverge into a random one.

In the terminology of assemblage theory, if this hypothesis is correct (and it seems that it is), relatively simple assemblages may produce arbitrarily complex expressions (that is, if they are not found to have trivially simple expression)[6]. Alan Turing's work on the universality of computation (Herken, 1992; Turing, 1937) had already established that any computing device of whatever structure that can be shown to emulate a certain abstract configuration of rules called a "Universal Turing Machine" (UTM) is capable of executing arbitrarily complex computations. In other words, if something can be computed at all it can be computed by a UTM and every actual structure that can be shown to constitute a UTM is therefore a universal computer. Nevertheless UTMs are very specific and need to be specially designed. Wolfram's principle of computational equivalence makes the following extension to the UTM idea: even if no particular design effort is invested, very simple structures might be capable of producing the outcome of an arbitrarily complex computation *at some point* in the course of their ongoing behaviour and this is irrespective to their initial conditions. In Wolfram's words:

> "So far from universality being some rare and special property that exists only in systems that have carefully been built to exhibit it, the Principle of Computational Equivalence implies that instead this property should be extremely common. And among other things this means that universality can be expected to occur not only in many kinds of abstract systems but also in all sorts of systems in nature. [...] According to the Principle of Computational Equivalence therefore it does not matter how simple or complicated either the rules or the initial conditions for a process are: so long as the process itself does not look obviously simple, then it will almost always correspond to a computation of equivalent sophistication. And what this suggests is that a fundamental unity exists across a vast range of processes in nature and elsewhere: despite all their detailed differences every process can be viewed as corresponding to a computation that is ultimately equivalent in its sophistication." (Wolfram, 2002, pp. 718-719)

What this hypothesis means for our case is that even under the simplifying assumptions we made, the potential wealth and variety of expressions is not generally

[6] Implicit in Wolfram's analysis is the assertion that the vast majority of computational processes are not "obviously simple" meaning that they cannot be simplified by mathematical descriptions.

bound by the structures that produce them. The intuition that simple structures are capable of producing only simple behaviours and only complex structures are capable of producing complex behaviours is wrong. Consequently, while it is true that the combinatorial proliferation of structures does not necessarily imply the proliferation of expressions, it is nevertheless the case (given that Wolfram is right) that the wealth of expression is unbound because even very simple structures can produce such wealth. This might seem at first sight almost trivial but it is not. It supports the hypothesis that reality is infinitely rich and possesses a richness which is relatively easily accessible due to the relative proliferation of simple structures. Inasmuch as the virtual is an inexhaustible source of Ideas so is the actual a correspondingly inexhaustible source of manifestations of such Ideas.

8.6.2 Innovation in Populations of Complex Individuals

Here we address the problem of finding combinatorial structures with significant expressions in the vast search space of all combinatorial structures. First, we provide a simplified formal description of assemblages as strings. Generally, an assemblage could be modelled as a connected graph where vertices represent elements and edges represent interactions, both of which are labelled to indicate the different kinds of elements and interactions. For example, we can easily represent the structure by providing a list of doublets (V_i^k, V_j^l) where the subscript specifies ordinal index and the superscript the kind of element. Implicit in each doublet is a unique interaction depending on the kind k, l of the interacting elements. Structures may change by elements joining or leaving them or by elements being replaced by others. These could be easily represented by adding, omitting or modifying doublets in the list. With such representation, assemblages of maximum n elements can be encoded into strings of maximum $N = n^2$ symbols each representing a doublet. For simplicity we can include a null element (signifying an absence like space in text) and have all possible assemblages of up to n elements represented by a string of constant length N. If the number of different elements including the null element is $m \geq 2$, we will need $S \leq m(m-1)/2+1$ different symbols to encode any interaction including a no-interaction symbol. This is of course only one option of encoding. The important point is that complex assemblages can be represented and manipulated as strings. The number of different structures would therefore be S^N that even for modest numbers of elements tends to be very large. Even if $S = 2$ (e.g., encoding whether elements are connected or not), we would remain with 2^N possibilities, which is exponential with N.

The notion of structural distance between two assemblages is defined as the minimal number of single changes (i.e., changing a symbol in one location in the string) that need to be made in one assemblage in order to transform it into the other one. We assume that single structural changes are significantly more probable than multiple simultaneous changes and therefore with good approximation relate to multiple changes as sequences of single changes. Geometrically, the space of all assemblages can be represented as a multidimensional structure where each vertex represents a single unique assemblage connected to its $N \times (S-1)$ 1-neighbours, that is neighbours reached from the point of origin by introducing a single change. Accordingly, a n-neighbour of an assemblage is any assemblage of distance n from it. The diameter of such geometrical structure is defined as the farthest distance possible between any two assemblages. Given an assemblage structure T, in order to reach any other assemblage $\overline{T}$ of maximal distance from T, one will need to perform a maximum of N unique symbol changes (which yields $(S-1)^N$ maximally different assemblages). Notice that though the space of different possible assemblages is vast, its diameter $D_{max} = N$ is relatively small. One can reach from one assemblage to any other assemblage by merely $d \leq N$ steps.

Highlighting the combinatorial nature of assemblages, we can address the problem of innovation. In this model, innovation amounts to finding novel expressions by introducing structural changes. But these are not easy to find. We can safely assume that the number of relevant different expressions in their milieu is only a vanishingly small fraction of the number of different structures. For example, from the vast number of DNA molecules only a vanishingly small fraction encode viable phenotypes. From all strings of characters, only a vanishingly small fraction are intelligible texts. From all possible chemical reaction networks, only a vanishingly small fraction may yield stable chemical organizations (Dittrich and Fenizio, 2007) etc. Likewise, in the more general case of enactive systemic cognition, only a vanishingly small fraction of all assemblages may yield autonomous closures in their interactions, and searching for such assemblages in the vast space of possibilities is like trying to find a needle in a haystack. How would one expect to find anything interesting within a reasonable time frame relying solely on contingent perturbations that introduce random changes in the structure of assemblages? Common sense would support that the emergence of complex structures based solely on contingency and blind trial and error would take a prohibitively long time to happen, if at all. Furthermore, even if a complex assemblage with a significant expression has somehow individuated, it is very likely that random changes to its structure will destroy it and very unlikely that such changes will produce another innovative expression. This is simply because it seems that there are always many more ways to change something for worse than to improve it. Here we are going to show that innovation stands a chance much more significant than common sense would lead one to estimate and this is due to the distributive nature of populations.

In his book *The Origins of Evolutionary Innovations*, Wagner (2011) constructs an argument that shows how combinatorial productivity, i.e., a random walk in structural possibility space, may yield, under certain general assumptions, innovation within a plausible time frame. The following sketches an adaptation of Wagner's argument, where the structure and expression of assemblages correspond to genotypes and phenotypes respectively in Wagner's analysis in the biological context (ibid., chap. 6). In his analysis, Wagner already notices that his results are equally applicable to a number of very different cases in biological systems. We take his generalization a step further based on two observations: the first is that it is possible to describe individuals as assemblages (and populations of individuals as populations of assemblages) in terms of their structure and expression. The second observation is that the properties of structures instrumental to the argument are based on relatively simple and context-independent graph theoretic derivations. Admittedly, the following formal analysis is crude and would require much refinement when applied to a specific context but it provides a qualitative sense of how a transformative process of individuation would work.

Consider a population of assemblages P represented (as above) by strings of length N of S symbols. The maximum number of different structures in the population would be $T_{max} = S^N$ and the total number of different expressions can be assumed to be $X_P \ll T_P$. Given a unique structure T^i with an expression X, the robustness $0 \leq \nu \leq 1$ of X can be defined as the fraction of the 1-neighbours of T^i that have the same expression as T^i. This can be simply be interpreted as the probability of the expression to remain the same when T^i undergoes a single structural change[7]. A *structure network* is a connected graph of structures that have the same expression[8]. We construct a random structure network by starting with an arbitrary structure T^0 and connecting to it a fraction ν of its neighbours chosen randomly. The resulting network has a diameter of 1. Iterating the construction step on each of the 1-neighbours of T^0 we get a new set of nodes added. Most of these are 2-neighbours of T^0 but not all of them. Some can remain within the 1-neighbour set or even return to T^0. This construction step is repeated to produce a connected network of structures with an identical expression. We denote the whole network as T and its particular nodes as T^i.

At some stage, say after k steps, the diameter of the constructed network will not change any more. To see why, consider T^k to be a k-neighbour of T^0. We can ask what is the probability of a 1-neighbour of T^k being a $(k+1)$-neighbour of T^0. Only $(S-1)(N-k)$ such neighbours exist out of a $(S-1)N$ possibilities of random construction choices, which yields a probability $1 - k/N$. At the $k+1$ construction step each k-neighbour of T^0 will be connected to $\nu(S-1)N$ additional randomly chosen nodes, some of which are already in the graph of course. Since each choice of a new node is independent, the number of newly added nodes that are $(k+1)$-neighbours of T^0 follows a binomial distribution with parameters $n = \nu(S-1)N$ and $p = 1-k/N$. The expected number of additions at the $k+1$ iteration would therefore be $np = \nu(S-1)(N-k)$. We need to know what k is, for which $\nu(S-1)(N-k) < 1$, i.e., probably no more additions. This k is the expected diameter of the structure network we constructed randomly and gives an estimation as to the diameter of specific (i.e., not necessarily randomly constructed) structural networks. It would be

[7] We assume ν to be a global parameter but of course in actual cases expressions may differ in their robustness.

[8] In the terminology developed so far, structures with the same expression are repetitions (as described in chapter 4) and the structure network is a multiplicity territorialized via a single expression.

instructive to express this diameter in terms of a fraction of the maximum diameter of the population $k/D_{max} = k/N$:

$$D = \frac{k}{D_{max}} = \frac{k}{N} > 1 - \frac{1}{\nu(S-1)N} \tag{8.15}$$

The important insight this result provides is that given enough heterogeneity in elements and large enough assemblages, a connected network of assemblages having the same expression spreads nearly the whole way across the space of possibilities, even for relatively low values of ν. The size of such structure networks, however, is expected to be marginally small compared to the size of the possibility space. As we need to choose k string elements to change and each location can be changed in $S-1$ different ways, the number of k-neighbours for each initial structure T^0 would be given by:

$$(S-1)^k \binom{N}{k} = \frac{N!(S-1)^k}{(N-k)!k!} \tag{8.16}$$

The fraction of these belonging to any structure network with robustness coefficient ν would be:

$$\nu^k (S-1)^k \binom{N}{k} \tag{8.17}$$

Summing all the contributions for all values of k yields:

$$size(T) \approx \sum_{k=0}^{N} \nu^k (S-1)^k \binom{N}{k} \tag{8.18}$$

This estimation compared to the size of the possibility space S^N is a tiny fraction when N is even moderately high. For example, for $N = 100, 2 < S < 20$ and $\nu \approx 0.5$ the fraction would be of the order of $10e - 20$ and this number goes down very fast with decreasing ν (see: (Wagner, 2011, p. 88)). This estimation makes another important point: if any single structure network occupies only a tiny fraction of the possibility space, then such possibility space may be populated by a very large number of such networks, each with its unique expression. But the way such structures are spread in possibility space makes them highly enmeshed within each other. There might of course be a number of unconnected structure networks having the same expression but a further graph theoretical result shows that with probability approaching 1, there will be a single giant structure network if the following parametric conditions hold:

$$\nu > 1 - \left(\frac{1}{S}\right)^{\frac{1}{S-1}} \quad and \;\; N \to \infty \tag{8.19}$$

For a moderately large $S = 10$, ν would only need to be greater than 0.22, while for $S = 100$, ν it would need to be only greater than 0.04.

The final point is estimating the diversity of expressions accessible via one change from any member of the structure network T. The simplifying assumption made here is that there are $X_P \ll S^N$ different expressions that are uniformly distributed among all the possible structures. Consider any two particular structures T^i, T^j on T. The number of 1-neighbours of T^i which do not belong to T can be given by $(1-\nu)(S-1)N$ and the probability of finding a specific expression within this set of 1-neighbours is $p = (1-\nu)(S-1)N/X_P$. What then would be the expected number of 1-neighbours of T^j having the same specific expression? Again we have a binomial distribution with p and $n = (1-\nu)(S-1)N$ because we have n chances to reach a structure with the same expression. The expected value is therefore:

$$\frac{(1-\nu)^2(S-1)^2N^2}{X_P} \tag{8.20}$$

It is not generally the case that X_P is greater than the numerator but plausibly it is. Though the number of expressions is much smaller than the number of possible structures, it is still related to S^N which is vast even for moderately large N. A uniform distribution of expressions over the structure space is not very realistic as particular expressions will tend to cluster around particular structures. But even then, different neighbourhoods across a structure network will tend to be well diversified. If there are no prohibitive context-dependent constraints on the size X_P, we will hardly find unique expressions shared by any pair T^i, T^j on T. In other words, though it is a very crude estimation, any structure network T is highly diverse in the expressions accessible via a single change from one of its particular structures.

To appreciate the significance of this point, we need to apply population thinking. Our population of assemblages P exists and interacts within a much larger milieu M of other assemblages that have selective influences on P. Such selective influences may cause only certain expressions or even a single expression X to be displayed by$P$. We would say that X is the only one 'fit', in the sense that its corresponding structures (belonging to the structure network T) do not disintegrate in the course of the current interactions with M. There is, however, a whole subpopulation of assemblages in P with expression X. Even if all of them are initially of the same exact structure T^0 and given sufficient robustness, under ongoing perturbations they will progressively diverge across the structure network T that corresponds to X. Consequently, the number of innovative expressions (differing from X) accessible as 1-neighbours to the whole population as a single individuating entity will proportionally grow as the subpopulation of fit structures diverges and spans across the possibility space.

It is this accessibility of innovation within a single change available from any currently fit expression that is the point of the whole argument. Remarkably, it is the robustness of a certain expression under structural changes that promotes the innovability of the population under the selective constraints imposed by the milieu M. The diversity of a population in the corresponding structural and expressive aspects allow any expression that is presently fit either to remain stable while drifting across its structure network T, or, when the opportunity is present (i.e., M changes and other expressions become viable or even fitter), to change into any one of a large variety of different expressions in a single structural change. In fact, given that M changes slowly enough to allow for our population of assemblages to drift all across the structure networks corresponding to the set of viable expressions in that M, a very large variety of alternative expressions can be tested for viability at any given moment through single changes in structures. These changes may occur in parallel in many structures of the population. Such a feat of exploring the vast possibility space is only possible due to the distributive character of populations. It might seem that robustness and innovability should have been antagonistic properties. But almost paradoxically this is not the case. It is exactly the robustness property combined with heterogeneity that supports immediate access to a great number of possibilities of expression and hence to innovability much greater than one would expect[9].

8.6.3 Innovation Spaces

The argument presented thus far supports the case that given already established populations of complex individuals (with corresponding structures and expressions), innovation is accessible and can be effectively explored all across the possibility space and under the selective constraints present in the milieu M. This encompasses many important spaces of actualization for assemblages, such as the space of chemical compounds, the space of genotypes, the space of neural configurations, the space of computer programs, the space of linguistic expressions etc. These spaces are vast and the innovation that can be found in them is virtually inexhaustible. Furthermore, gradual increase in complexity can take place within such spaces by merely increasing the size of assemblages within existing spaces. For moderate heterogeneity such as $S \geq 10$, an increase of an order of magnitude in the number of possible structures is achieved just by adding a single element to an assemblage. Yet, as in the example of grains of sand, more is not always more significant. Increase in innovability is not automatically warranted by merely increasing structural complexity but it is not implausible.

Much more intriguing are those events where a population of an entirely new kind of assemblages emerges, embodying a new space of innovation. These are truly singular, disruptive and (relatively) rare events. They can be identified and characterized only in retrospect since their occurrence does not seem to follow a single general mechanism or principle. As already discussed in 8.3 every such population is characterized by a set of individual building blocks capable of combining to produce large numbers of almost arbitrarily large assemblages. The combinatorial mechanisms are often (but not always) simple and uniform, that is, each element connects to other elements in the same manner (e.g., forming chains of elements), or

[9] A bit more involved development shows that some robustness $\nu > 0$ is not only sufficient but also a necessary condition to the existence of structure networks which is critical to the argument (see: (Wagner, 2011, pp. 89-90)).

following a small number of relatively simple options (e.g., the case of atoms). This is also associated with the emergence of a coding system as discussed in 8.4. In all cases though, the formation of assemblages must be probable and the supply of the material elements abundant[10]. These conditions are necessary for the formation and further development of such populations.

Apparently, the emergence of a new innovation space is serendipitous and the characteristics of the already known instances of such spaces contribute very little if at all to predict a future occurrence. In the light of the metaphysical framework developed in this work, the unexpected should be expected because thought and cognition in the broad sense discussed here are open-ended and there will always be events that break through the boundaries of what is known and what already exists within established innovation spaces. There is, however, a deeper point to be made. We are trained to distance ourselves from the unknown. We try, with a large degree of success in many cases, to tame the unknown into probability distributions, predictions and inference methods (not to mention a great deal of non-scientific approaches). There is even a universal inference principle (Solomonoff, 1964a,b), justifiably considered an ingenious mathematical breakthrough, that instructs what is the best practice of inference with minimal or no prior knowledge. All these are utterly ineffective when it comes to contemplating events that are truly singular and have no previous reference. These cannot possibly be predicted, inferred or intuited. There is no probability distribution to a single event and prior to its appearance it is simply unknowable. This is indeed the nature of difference and the nature of thought sans image. It is simply (and practically) a thought that has no support. But these singular events, when they appear, they appear at once as multiplicities and interact as multiplicities within a milieu of multiplicities. As such, they beget stable expressions like surfaces, which hide the depth of untamed difference underneath them. Only very rarely, there is an event which is so disruptive that it breaks all previous surfaces of apparent stability and introduces a new innovation space. The appearance of life is such an event, the appearance of language is such an event and there are quite a few others of lesser significance and scope. These and only these are glimpses of the *new as such* – an eruption of intelligence unbound by necessity.

[10] A concept strongly associated with the emergence of innovation spaces is the concept of replicators (Von Neumann and Burks, 1996). In brief, a replicator is a system capable of self-reproduction with some limited variation. DNA and RNA together with their self-encoded replication machinery are the classic examples of such systems. Self-replication brings forth heterogeneous and diverse populations and thus spans vast innovation spaces, prominent among which is of course the phenomenon of life with its immense diversity. Yet it is important to note that not all innovation spaces originate from self-reproduction. Two examples are atoms that span the space of chemical compounds and eukaryotic cells that prompted the proliferation of complex multicellular lifeforms. While eukaryotic cells are self-replicating entities, it is not this property that enabled multicellular life but their ability to cooperate and specialize.

Chapter 9

Interactions

9.1 Understanding Interaction

When predator and prey happen to meet, they engage in an intricate dance, where the predator tries its best to make the prey a meal while the prey tries its best to avoid becoming a meal. Mating rituals among animals may be even more complex as the intent to mate or not to mate is itself a variable often determined only in the course of the exchange. An engaging conversation between two or more persons, a debate or a heated argument carried out on multiple planes of exchange (e.g., methodical arguments, the use of specific provocative words or idioms, intonation, pitch and volume, facial expressions, eye movements, body gestures and at times even the more or less subtle changes of body odours), the collision of subatomic particles, chaotic weather systems, the dynamics of markets and large scale social systems, these are all examples of complex interactions.

In this chapter we aim to demonstrate the profound role that interactions have in bringing forth actual individuals, in determining actual properties and in realizing the inherent tendency of certain systems to self-organize and spontaneously manifest in distinct and relatively stable objects and relations. By interaction we mean a sequence of actions exchanged among agents that is initiated by an agent and unfolds in a chain of effects that returns, eventually, to affect its point of origination through at least one path. All agents connected along a closed path of activation necessarily interact with each other. Within such closed paths of activities, we will show, serendipitous exchanges may organize into persistent systems of interacting individuals.

In this context the ancient symbol of the Ouroboros comes to mind. The Ouroboros continuously devours itself in order to reconstitute itself. In the terminology developed in this work, the devouring and reconstitution symbolize the movement away from an individuated distinct form into a less individuated one and then the movement of determination that brings forth a more individuated form. Such activity must be carefully coordinated. If the Ouroborus consumes itself too fast it will eventually damage an essential organ and die. If it consumes itself too slowly, it will become petrified and the vicissitudes of time will bring about its demise all the same because it will not be able to adapt to change fast enough. This careful dynamic balance between preservation and transformation is the core idea of cybernetics. This idea finds its myriad realizations in interaction. All actual expressions consist of interactions at some level.

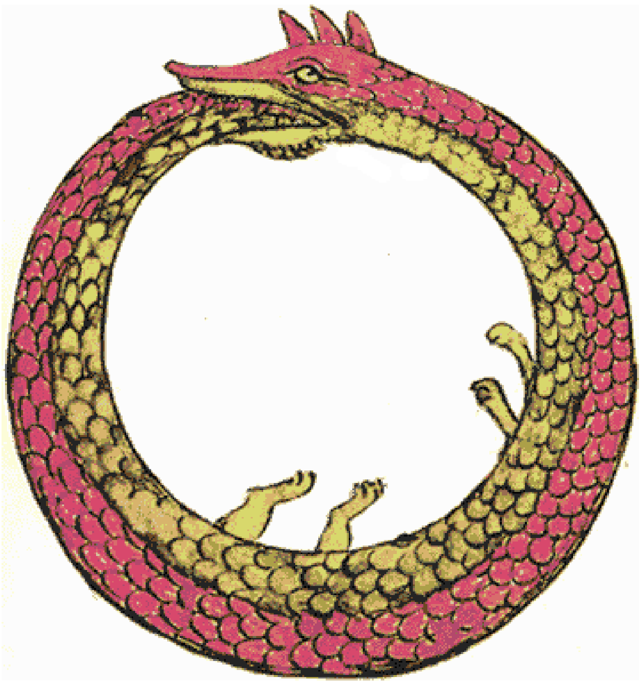


Figure 9.1: The ancient symbol of the Ouroboros depicting a serpent biting its own tail symbolizing interaction – an action that returns upon its point of origination to affect it. The psychologist Carl Gustav Jung saw in the Ouroboros the archetype of psychological individuation – the process in which the individual self develops out of an undifferentiated unconscious (see: (Jung, 1963, pp. 431-432),(Jung, 2014, pp. 275-289))[1].

9.2 Complex Adaptive Systems (CAS)

The combination of population thinking and cybernetic interactivity gives rise to the very useful concept of Complex Adaptive Systems (CAS from here on). First coined by John Holland (Holland, 1992, 2012), a CAS is a heterogeneous population of interacting entities called agents. The activities of CAS are distributed and asynchronous, as agents are continuously adapting their own behaviours to changing circumstances caused by the behaviours of other agents. Adaptive behaviour normally implies a certain set of criteria or values to be optimized or held invariant but adaptation can in many cases be not more than some correlated responsiveness. A CAS is not a system in the classical sense because there is no global organization, goal or principle guiding the activities of CAS. Neither the characteristics of the agents nor the topology implied by their interactions is presumed. The number of agents, their properties, behaviours and interconnections are all variable and

[1] Out of space considerations I have not dedicated to the fascinating topic of the individuation of the human psyche the attention it deserves.

are often unpredictable. As a whole, CAS are capable of presenting complex and sometimes creative global behaviours. The general characteristics of CAS derive primarily from the nature of the agents considered given in terms of their properties, behaviours and capacities to interact, the size of the population, its distributiveness, connectivity and heterogeneity. Prominent examples of CAS are ecosystems, financial markets, brains, social systems, living cells, beehives, cancerous tumours, the internet and more.

In Holland's description, the agents involved are described as collections of formal interaction rules called *classifier systems* which are basically sets of IF/THEN predicates (Holland, 2012, chap. 2-4). The rules associate input signals (perceptions) to output signals (actions) and also allow inner states. Rules place 'bids' to be executed if certain conditions on the input hold. If a rule wins the bid and it is successfully executed it is rewarded with a predetermined reward. The net gain (after deducting execution costs) of any rule increases the probability of it winning bids in future occasions when the agent is triggered to act by similar conditions. This reward mechanism introduces a dynamics of both competition and cooperation among various rules or groups of rules. The rule system of every agent undergoes a continuous process of evolution by means of a genetic algorithm which is meant to simulate a Darwinian evolutionary process (ibid., chap. 6). Successful rules are recombined to produce new 'offspring' rules that are tested and competed against existing rules in the consequent interactions.

The global rule system developed by Holland is a coding system that has in mind a very specific kind of function – simulation by a digital computer. It is a perspective that neglects the singular features of intrinsic coding systems that emerge in actual specific cases. The idea of introducing an artificially constructed coding system is grounded in the hypothesis that it is possible in principle to construct a universal coding system so that all specific coding systems can be given as its special cases. This idea belongs to a family of similar ideas such as the Universal Turing Machine for which all computations are special cases, or the idea of a universal grammar for which all natural languages are special cases. Coding systems, however, are themselves individuals. They are rarely artificial constructions but products of an historical process of individuation. They can indeed be approximated by a general formal system but are never fully captured by such a system. The problem arises not due to the artificiality of the construction but rather due to the inherent uniqueness of individuals. This point is demonstrable in attempting to translate from one individuated (as opposed to constructed) coding system to another. For example, in translating one natural language to another, there is always some nuance that is lost in translation and in many cases the nuance might be critical. This nuance is the ultimate manifestation of difference – the unequal that can never be equated or eliminated by reducing it to formal elements. In CAS, therefore, attempting to apply a single overarching formalism that makes agents fully representable, even while evolving, loses an important sense of their becoming and uniqueness. Here, we can see the difference between an approach that takes unity as a fundamental reality and the complex of ideas and approach developed in this work that takes multiplicity as a fundamental reality. CAS, we claim, are fundamentally multiple. There is no overarching formalism by which realistic CAS can be fully represented.

In the terminology developed in this work, CAS are fields of individuation. We are interested in CAS as an abstract framework that integrates many of the ideas discussed thus far and in this our usage of the concept departs from Holland's attempt to formalize it. With this description in mind, agents and interactions are assigned only the minimal representation required to describe processes of individuation. They are didactically described within a specific stratum along with its two adjacent strata: the substratum where the agents of the stratum are themselves undergoing individuation and the superstratum where the individuated assemblages of the stratum operate and interact as higher level agents. Every stratum delimits a plane of activity given to observation within a larger and theoretically unbound field of individuation. Within their stratum, agents interact. In the course of interactions they form assemblages. Assemblages individuate, form boundaries and eventually become integrated agents of a higher stratum. This activity may develop recursively across many strata and form hierarchies of agents and interactions. Additional constraints can of course be added to this abstract framework in order to further characterize a specific CAS or empirically investigate an actual system.

9.3 Reciprocal Selection and Determination

In the context of evolutionary dynamics, the concept of adaptation has an obvious meaning: the modification of structure and behaviour of the organism for the purpose of increasing the probability of survival and procreation, that is, increasing fitness. In the discussion developed in chapter 7, a similar reasoning is deployed to explain cognition as an adaptive regulative activity facilitating the continuation of autonomy. It is easy to address adaptation as a kind of a purposeful activity of an agent towards the goal of ensuring continuity. Such activities take place in relation to a milieu and across a boundary that distinguishes what it is that continues and against what background. If there is no distinct boundary there is little point in speaking about the continuation of anything. The persisting organization of an agent can always be given in terms of boundaries and constraints on change, whether spatial or temporal.

From the perspective of such an agent, whatever perturbations that originate from the milieu are indifferent to its own continuation. Some perturbations might be supportive to the continuation of the agent, others detrimental and perhaps the vast majority neutral. Operating towards its continuation the agent's activities must therefore consist of selection. First, selecting out all the non-relevant perturbations, and second, biasing the effects of external perturbations towards increased fitness. This would mean trying, by exerting actions, to reduce the effects of detrimental perturbations while amplifying the effects of the beneficial ones so that at least they remain in neutral balance. Yet, the selections of the agent's activities would be random or blind if it could not be somehow informed as to the consequences of its own selections. In other words, for this scenario to make any sense at all and for the agent to have any chance to persist, it must be engaging in interactions with its milieu. Interactions that will allow it to correlate actions to their consequences. Furthermore, its future selections must, at least to some extent, be informed by the consequences of past selections.

The story of adaptive behaviour is based on an already formed agent with certain properties and capacities, prominent among which is an express bias towards existence. In the more general case of CAS as a field of individuation, an obvious question is how agents come into existence in the first place. Furthermore, in cases where the maintenance of individuality is passive, purposeful adaptive behaviour is not obviously demonstrable. If CAS are fields of individuation we need to address adaptivity in a broader sense that accounts for how agents individuate via reciprocally determining interactions (see 7.2.4).

9.3.1 Spontaneous Emergence of Reciprocal Selection

It is argued that even in the case of random interactions in heterogeneous populations of primitive agents, one can expect reciprocal selection and mutual determination of behaviours among agents towards the individuation of more complex and diverse agents. This can be illustrated by a simple though somewhat involved example supporting the claim that even prior to the emergence of complex adaptive individuals, and before adaptive behaviour as such is demonstrable, CAS are already fields of individuation and emergent complexity.

Consider a population of simple agents A_n with a repertoire of N unique I/O signals S_i. A simple behaviour $B_{i\times j}$ of an agent is a set of N IF/THEN rules: if triggered by input signal S_i it then responds by outputting S_j, or in short: $R_{ij} := S_i \to S_j$. The number of different rules is N^2 but there is quite a large number of possible different rule sets equal to the number of different combinations of N rules, that is, N^N (N possibilities for the first rule times N possibilities for the second etc. till N). Assume that all sets of rules are equally represented in a large population, each with probability $P = 1/N^N$. Out of the population we pick up randomly two agents and connect them so one's output is connected to the other's input to form a 2-agent interaction loop. The number of different interaction loops will be:

$$(N^{2N} - N^N)/2 + N^N = N^N((N^N - 1)/2 + 1) = N^N(N^N + 1)/2$$

We also notice that due to the way agents can connect, they can only form simple linear chains and simple interactive loops where such chains close. The manner by which each agent translates the output of its preceding agent to the input of its following agent is such that any loop of length L can be reduced to an equivalent loop of two agents. Suppose we have a loop of L agents. Each signal S_i at the output of the first agent A_1 will be transformed by some sequence of rules $R_{ij}, R_{jk}, R_{kl}, \ldots, R_{yz}$ of length $L-1$ into some signal S_z as it propagates from agent to agent along the chain. This sequence can be replaced with a single equivalent rule R_{iz}. We can repeat the replacement procedure for all the N possible output signals from A_1 and by this construct a single set of equivalent rules. We now can replace the $L-1$ agents in the loop with a single equivalent agent A_2 defined by the set of rules thus constructed (it is necessarily a member of the population). We need therefore to examine only configurations of two agents A_1, A_2.

Suppose agent A_1 has some rule R_{mn} and agent A_2 has a complementary rule R_{nm}. If A_1 happens to be triggered by S_m (which is basically an initial condition), the joined agents will produce a recurrent sequence with period 1: $S_n, S_n, S_n, \ldots$ at the output of agent A_1 and similarly a sequence $S_m, S_m, S_m, \ldots$ at the output of the other agent. In a similar manner, recurrent sequences with period 2 can be produced. For this we will need a more complex combination of pairs of rules in A_1 and A_2. If, for example, $R_{ij}, R_{kl} \in A_1 \wedge R_{jk}, R_{li} \in A_2$, triggering A_1 with either S_i or S_k will result in a recurrent pattern of period 2 ($S_j, S_l, S_j, S_l, \ldots$ and $S_i, S_k, S_i, S_k, \ldots$ respectively) at the outputs of both agents. Notice that in both cases and also in cases of longer periods, there are usually more than one combination of rules that produce a sequence of a given period (e.g., $R_{ii} \in A_1 \wedge R_{ii} \in A_2$ for sequences of period one).

Beyond sequences of period 2 we discover something which is both trivial and interesting. The signals appearing in any sequence must be different from each other. Let us, for the sake of simplicity, annotate every signal S_x with its index x. If for example we have 3 signals a, b, c, only their 6 permutations abc, acb, bac, bca, cab, cba can appear in a periodic sequence (actually there are only 2 distinct sequences because abc,cab and bca are only shifted versions of each other). Periodic sequences such as *aabaabaab*$\ldots$ or *cbccbccbc*$\ldots$ can never appear. The reason for this is that once a sequence begins it will, due to the deterministic structure of the agents, start repeating itself once any of the signals reappears. In other words, a sequence can continue and become longer if and only if none of the signals that already appeared in it reappears. In our closed loop configuration, any input to any of the agents determines its next input always in the same manner. If a signal repeats, everything that will follow will repeat. Since the number of different signals is limited to N, repetition is ensured and the longest repeating sequence will be of length N.

This repertoire of behaviours is not implicit in the definition of the agents but emerges in their interactions. The so called 'preference' of recurrent sequences of non-repeating signals is a result of how the rules combine. The point is that the agents' behaviours are defined as relations between signals, whereas the interaction between agents relates behaviours not signals. It is indeed the case here that the relation between behaviours is rudimentary but the said global preference is a result of this relation and not of any specific rule or a stand alone set of rules.

Even with such a highly simplified scenario of CAS (no adaptation is possible), a population of randomly assembled interactive configurations presents significant organization and richness of behaviour. By merely interacting, agents are *selecting* each other's behaviours. This is true since the output of one agent determines the rule that will be applied by the agent fed by it. With these reciprocal selections, the behaviours of the involved agents become constrained and correlated to each other (the example is pretty radical in this respect). The local reciprocal selections do possess a clear global selective and organizing effect that is observable at the population level in the characteristics of the signal sequences being produced.

Interactive configurations can be related as individuated higher-level agents. The population of such higher-level agents could be further categorized, e.g., according to the number of the unique recurrent sequences a specific combination of agents can produce. This can be considered as a primitive defining property of the higher-level agents. Each unique sequence can be thought of as an attractor state to which the dynamic of the signals converges. All of the higher-level agents will have at least one such attractor, usually a single sequence of period one. But quite a few configurations will be able to produce multiple attractor states. We have created a program (documented with results in appendix sections 9.A-9.C at the end of the chapter) to sample the distribution of the number of attractor states per higher-level agent across the population of possible configurations. The number of attractors produced by any higher-level agent can be thought of a simple measure of its complexity (see ahead). Notice also that every attractor can be reached only from a subset of initial trigger signals. If there is a single attractor state, all the input signals will lead to it. If, however, there are more than one attractor states, each state will have a unique set of initial triggers leading to it. This feature clearly shows a diversification of properties that did not exist in the original population.

Another feature apparent in the population of higher level agents is the distribution of output signals. Out of the N^N different sets of rules only $(N-1)!$[2] sets produce at their output the full range of possible signals. The fraction of such sets $(N-1)!/N^N$ diminishes as N grows. All other sets will produce output repertoires smaller than their input repertoire. When agents are connected in an interactive loop they will, on average, tend to reduce the variety of each other's signals (see 9.4.1 ahead). Sampling the distribution of output sequences (see 9.B) shows that sequences (the attractor states) are heavily biased towards shorter sequences expressing fewer signals. This is also an outcome of reciprocal selection taking place between pairs.

Obviously what can happen with such a population of agents is still pretty limited. The population is diverse in terms of behaviours but not heterogeneous at all. To appreciate the possible contribution of heterogeneity consider, for example, adding two extremely simple kinds of agent to the initial population. The first is a 'forking' agent. It has one input and two outputs that replicate its input signal. The

[2]There are $N!$ permutations but every N are just linear shifts of each other.

second is a 'unifying' agent with two inputs and a single output. Given two inputs S_i, S_j, it will output $S_{(i+j)mod(N)}$ (the resolution rule can of course have many other definitions). The two additional kinds of agent will allow the formation of networks of agents and not merely linear loops. Moreover, the unifying agent may, depending on the unifying rule, have the effect that recurrent patterns that were not possible before become possible.

An additional interesting feature becomes available with the combination of an interactive configuration, as described above, with a unifying component. If the output of the second agent is fed back to the input of the first via one of the inputs of a unifying component, this configuration allows to externally inject specific signals into interactive loops. For higher-level agents with two or more attractor states, it means that the agent can be transitioned from one of its attractor states to another one by injecting the appropriate signal via the second input of the unifying component. This configuration is in fact a primitive state machine whose state transitions can be triggered by an input signal. As will be shortly shown in 9.3.3, state machines belong to a category of more complex configurations whose complexity corresponds to the number of their distinct states. This justifies why the number of distinct attractor states a higher-level agent is capable of producing is indeed a simple measure of its complexity.

We learn that even a relatively slight increase in heterogeneity of the initial population may contribute very significantly to both the structural and behavioural heterogeneity of the population of higher-level agents. In fact, this example is a caricature of what allowed unicellular organisms to evolve into multicellular organisms. The 'symbiosis' between any agent and the forking and unifying more primitive elements can yield agents with multiple input and output ports. This fundamentally changes what can happen. However, it will be hard to predict the effects of increased heterogeneity on the outcome of interactions beyond such simple examples.

The scenario described here is still far from exposing the power of interactions to form complex behaviours and individuations. It is merely an illustration that even random interactions between very primitive agents can readily yield an increase in complexity of behaviours. What is significantly missing from such primitive agents is a temporal dimension (though the primitive state machines illustrated above are a step towards forming a rudimentary memory of past signals). The behaviours are fixed and as agents thus described have no history (i.e., 'experience') relevant to their current state of affairs, they cannot develop or demonstrate anticipation, learning or adaptation of any kind. This temporal dimension is discussed in 9.3.3.

9.3.2 Equilibrium and Reciprocal Selection

In the classical cybernetic literature (Ashby, 1957, 1960) the idea of adaptive behaviour is based on the concept of equilibrium. The general assumption is that dynamic systems will tend to reach a final state called equilibrium or rest. For physical closed systems, equilibrium generally means thermodynamic equilibrium where the entropy of the system is maximized and all useful work – the kind of work that introduces relevant state changes – has been exhausted. The idea of equilibrium can be extended to general dynamic systems that are not necessarily physical, e.g., economic and social systems. On the condition that they are finite (in the number of component agents) and closed, all systems will eventually tend to a state of rest or at least to a state where some essential variables reach a state of invariance (see (Ashby, 1960, chap 3-4) and application to cognition (Clark, 2013, p. 186)). The condition of a general system being closed must be satisfied in terms of a system-defined quantity analogous to energy in physical systems that must be kept constant (conserved) at all times. The state of equilibrium or rest can then be understood as the state where all the energy is distributed more or less equally among its components so that any change of state will require an investment of energy external to the system.

CAS capable of reaching equilibrium must be interactive and this implies a mechanism of reciprocal selection between component agents. To keep the idea of a closed system simple we assume that all agents have at least one input and one output so the fact that a system must be closed or isolated means that all its component agents' outputs are redirected to all its component agents' inputs so no link remains unconnected[3]. Under such conditions, there must be at least one closed loop of activations in the system, that is, an interaction as defined in 9.1. To prove this we represent the system as a directed graph where agents are nodes and input/output connections are directed edges. We have only to notice that because every node has an output and the graph is closed, one can always travel to another node's input (also to itself). But because the number of nodes is finite, one is bound at some point to visit again a node that was already visited. This, however, leaves us with some nodes that do not participate in loops. It turns out that these must be part of lines of transmission that always start and end in nodes that belong to loops. We can see this by contracting each loop to a single node (in contrast to regular nodes which must have at least one input and one output, these contracted nodes may have only input(s) or only output(s)). Since the resulting graph is still connected and all non-contracted nodes still have at least one input and one output, going forward from each such node we will eventually reach a loop node and going backwards all the same.

If such a system reaches equilibrium what does it say about its inner dynamics? If we assume that the component agents are deterministic, meaning that given an input behaviour B_{in} it will always produce the same output behaviour B_{out}, let us examine two (or more) agents connected in an interactive loop. Similar to the previous example, every agent will keep changing its output behaviour as long as its input behaviour changes. The two (or more) agents will reach equilibrium, i.e., constant behaviours if and only if during the process of change the first agent will produce a behaviour B_1 that will select from the repertoire of behaviours available to the second agent one of the behaviours, say B_2, with the special property that it will

[3]This condition can be relaxed by ensuring that the unconnected links or agents with only inputs or only outputs do not hide a violation of the condition of closure.

select in the first agent the same behaviour B_1. Once such a condition is achieved, the behaviours of the agents of the loop will remain constant. This will be true also for more than two agents in the loop. As for the larger system, every agent that is fed by a loop that reached equilibrium will reach a constant behaviour as well. Last, loops that are also fed by agents that do not belong to the loop will receive at their entry point constant behaviours once all the loops with output edges reach equilibrium. Such loops will then proceed in their reciprocal determination process unaffected by the 'external' constant inputs and will reach equilibrium as well. The conclusion is that in all cases the proposition that a closed dynamic system always tends to equilibrium implies a process of reciprocal selection that culminates in constant behaviours (we omit from the sketch of proof here the details of a few more complicated cases such as a loop of loops, but these can be worked out following a similar line of reasoning). The example can be extended beyond constant equilibrium behaviours to demonstrate complex behavioural patterns that correspond to higher dimensional conservation rules (associated with high dimensional attractors e.g., limit cycles).

The phenomena of interaction and reciprocal selection is more general and can be applied to open-ended systems where global equilibrium is not ensured and cannot be assumed. The point is that in more general system configurations like CAS, the number of component agents and the whole architecture of the system is not necessarily definite. We can then think about agents containing a finite number of interactive loops placed within a larger milieu that interacts with the agents by means of exchanging signals. For each agent in such CAS, two cases to consider are:

1. The agent-milieu constitute together a closed system.

2. The agent-milieu constitute together an open system.

In the first case, we can proceed more or less with the same line of reasoning as above. The agent and the milieu engage in a process of reciprocal selection that can, at least in some cases, reach equilibrium, i.e., establish a coordinated exchange of constant behaviours or recurrent behavioural patterns (e.g., habits, policies, strategies). It is clear from this case that at the bottom line what adaptation means is a process of reciprocal selection in search of some global invariance that implies coordinated exchange of behaviours between the agent and its milieu.

The second case is more complicated. What would be meant by a system being entirely open? In the extreme it would mean no interactions and therefore no invariance and no structure whatsoever because ultimate openness means no limit on change. Invariance and recurrence seem to be products of interactions and ultimate openness can only mean action (and change) but no interaction. But even within a population of simple agents such as in 9.3.1, interactive loops emerge by forming random connections. So the open-ended case is never total. If it were the case no order or structure could actually exist. It follows that even in the second case, the relations agent-milieu will involve the spontaneous formation of recurrent patterns and structures. These might be fleeting but nevertheless persistent for a while. This is why the state of affairs of CAS in general – and here CAS can be understood as a descriptive frame of actual reality – is best described as metastable: temporary islands of permanence within a vast ocean of impermanence (see also 5.1.3.1). Agents that contain interactive loops may reach temporary equilibrium if they are not perturbed for a while in a way that disturbs their convergence. They may also move among a number of equilibrium states as will be discussed shortly in 9.3.3.

The order and structure observed in actual existence is always a product of a creative process, a becoming actualized via reciprocal selections between interacting agents at many nested strata. Yet, systems in the course of individuation need not be finite or strictly closed as is implied by the precepts of classical cybernetics. Neither need they achieve a state of equilibrium. Individuation, as Simondon remarked, is not an all or nothing property of something but rather a progressive process. Agents can become more or less individuated even without ever reaching final stability, or reaching stability for limited yet long enough periods to produce a sign, leave a trace and make sense to something other than themselves (see 9.3.5 ahead). The notion of stability itself becomes relational because there is no such thing as absolute constancy. To further understand individuation in terms not conditioned by a state of equilibrium, we next attend to a model of agents that involves an explicit temporal dimension.

9.3.3 The Temporal Aspect of Reciprocal Selection

Structural coupling, as discussed in 7.1.3, is perhaps a better model for studying the temporal aspect of reciprocal selection. To get an intuition as to how structural coupling works we extend the example discussed in 9.3.1 by describing agents as state machines (Ashby, 1962). A state machine agent is defined *a*) by a set of states each of which is a set of N IF/THEN rules like in the above model, and *b*) by each state having an additional rule called transition rule specifying the next state as a function of the current input. One way to understand states is to treat them as primitive experiences or 'memories', each prescribing a different behaviour given the same trigger signals. The various 'memories' are organized such that each memory state also 'anticipates' or 'associates' what will happen next and prepares itself by indicating its next relevant response, as if reasoning something like: "the situation X I am in is always followed by a situation Y if the current input signal is S_i. In situation Y it is best to respond to incoming perturbations like I already did in the past when I encountered Y. So if I am in state corresponding to situation X receiving signal S_i my next state would preferably be a behaviour corresponding to Y." Such specification of an agent may be either deterministic, that is, rules determine unique responses, or, probabilistic, that is, rules only specify probability distributions of responses and next states. The number of states and rules also determine the potential complexity of the behaviours the agents are capable of. The larger the memory is in terms of inner states the less predictable the agent's behaviour. This is because the larger the repertoire of states, the higher the probability that there are states that have not yet been visited in the course of observing the agent's activities.

State machines introduce an explicit temporal dimension to the activities of agents and their interactions in the form of their discrete state transitions. The present behaviour of an agent can depend not only on the input signal presently perturbing it but also on previous states and inputs that played a role in bringing the agent to the state it is currently in. Structural coupling is realized as the interactions among agents introduce in each long term structural changes manifesting in their behaviours. With state machines we can formalize the selection of non-trivial behaviours and its historical unfoldment.

How would individuation be described with this model? Assume a specific CAS with a finite number N of unique signals that can be exchanged among its agents. Consider a special agent with N^N states, each with a unique set of rules that maps the N possible input signals to one of the possible output combinations as in the example in 9.3.1. Also, the state transition rules randomly select the next states. This configuration is the 'anything goes' (ATG) configuration[4]. An ATG agent randomly explores the space of all possible behaviours and therefore it is the least determined agent in terms of behaviours. There is no way in which such an agent can be distinguished from any other agent. The reason is that given another agent with any finite set of behaviours (in terms of input/output pairs) that we may choose as a criterion of its distinctiveness, this very set of behaviours is also a possible set of behaviours presented by ATG agent with some probability.

Consider another special agent with N^N states like above, but the transition rules of all states point to a single state (that also points to itself) independently of any input. Such an agent is an ultimately constrained configuration (UCC) where after a single input it will lock into a single fixed behaviour. A state that points to itself irrespective of input is also known as *attractor state*. Once reaching such a state it can never escape. The ATG and UCC examples represent the two extremes of individuation. The former is the least individuated and the latter is the ultimately individuated with a fixed behaviour. In less restrictive configurations, a state machine may include one or more attractor states that designate ultimate and final individuation. But it is not given that any of the attractor states will ever be reached. Only if for every state in the machine there is a sequence of input signals that will transition it from that state (via possibly a long a number of intermediate states) into one of its attractor states, there is a finite non-zero probability for the machine to reach an attractor state provided that its input signals are not already prohibitively constrained.

Bearing in mind the examples demonstrating the extremes of individuation, let us consider a more interesting case where a general state machine contains subsets of states with the property that once any of the subset member states is reached, all the subsequent transitions, whatever the input signals are, will be only among the

[4] A simpler description exists with a single state of randomly chosen responses but we need here multiple states to make the point.

members of the subset. Such subsets are termed *attractor sets* or *closures*. The example of extreme individuation is just a special case of such a closure with a single state. Importantly, as a further generalization, state machines can be organized so that:

1. Closures may be contained within closures.
2. Closures can be signal specific, that is, they are maintained only under the condition that signals present at the input belong to a specific subset of all the signals. With such generalization, closures can be entered and escaped from, depending on the sequences of input signals.

A closure within a larger state machine can be thought of as a reduced state machine with less memory and less variations on its rules. The signal(s) that causes a transition of the state machine into any one of its closures is selecting a more restrictive regimen of possible behaviours in subsequent perturbations and therefore makes the agent more individuated. This can happen multiple times as transitions from a larger closure into smaller closures are triggered. An agent can transition from a more individuated phase to a less individuated phase by escaping closures. The dynamics within a closure always involve recurrent state transitions if they continue long enough. The limited number of states and limited number of signals can combine to produce complex recurrent behaviours.

Moving into, out of, and among closures, agents undergo phases of more or less stable behaviours and more or less determined behaviours. Signals can trigger phase transitions and actual behaviour changes of agents. With agents modelled as state machines a vast repertoire of behaviours can be generated, including recurrent patterns of any length, pseudo random patterns, and any combination thereof. The important point here, however, is how state machines can become more or less determined in their overall span of behaviours depending on their coupling with other state machines.

Considering CAS as a population of agents modelled as state machines, agents become coupled by forming networks and exchanging signals. Networks are formed by allowing agents to sample a number of input streams simultaneously or at least have some switching mechanisms allowing them to sample systematically the outputs of other agents. In the course of signal exchanges, agents are selecting and constraining each other's behaviours by moving the respective state machines into (and out of) closures. The range of complex behaviours is vaster compared to the previous examples, but importantly there is a sense in which the agents can be said to be adaptive. Every agent can be thought of as realizing a range of behaviours as closures. Moving among these closures represents adaptation to various external signals. Adaptation phases may also be considered as more or less specialized, depending on them being more or less individuated. Furthermore, in CAS dynamics, subsets of states *belonging to different connected agents* can form joint closures. Such joint closures are in fact state machines emerging in the course of ongoing interactions between two or more agents. The behavioural patterns produced by such joint state machines represent coordinated activities among the agents but can also further individuate and become more distinct from the agents that initially produced them. This is how boundaries among agents may reform. Notice also that state machines emerging in the course of interactions clearly correspond to how enactive cognition and the 'bringing forth of a world' are described in chapter 7. Finally, in the bigger picture of modelling CAS with state machine agents, a network of state machines can be clearly seen as a vast state machine joining together all agents, and where the boundaries among agents can form and reform as some agents emerge or disappear in the course of perpetual self-organization. From an empirical perspective, what individuates agents and makes them distinct entities are the observable recurrent patterns of interaction by which they can be identified.

Another level of complexity can be added by modelling agents not merely as state machines but as Turing Machines capable of performing any computation. These machines will feed each other's I/O streams and reciprocally select each other's computations. The only reason to mention this is to make the point that beyond a certain level of complexity, there are no shortcuts that will allow us to realistically predict in advance the behaviour of agents or their interactions. The only way to find out will then be to let the actual interactions take place and observe the unfolding behaviours. Since computing itself is a physical process, even with vast computing resources the simulation of certain processes is limited by the performance of the best known algorithms, which are sometimes provably the best possible and these cannot be run 'faster than reality'[5]. Here a limit is reached where computation *equals* actual individuation as past results cannot inform consequent outcomes. This individuation, however, is strictly the individuation of the simulated CAS and *not* of the CAS being simulated. As we have already discussed in 9.2 there are inherent limitations to representing individuating systems.

Zooming out from this level of detailing, as the actions of the agents intervene in each other's ongoing structural transformations, they each become an influence on the other's individuation so eventually they individuate jointly. Remarkably, joint individuation does not predict that the two (or more) agents become one integrated agent or remain distinct from each other. This will depend on the specific nature of the interactions. For example, the coevolution of predator and prey species may bring the prey species to develop progressively better camouflage and the predator species progressively sharper sight while all along their coevolution they remain distinct. Or, two interacting species may enter symbiotic relationships and become a single individual organism e.g., lichen (fig 9.2) which consists of algae and fungi. This combination is so successful that many species of lichen exist by partnering

[5] In 8.6.1 we mentioned rule 110 – a cellular automaton where no computational shortcut is known to predict its future output pattern. The automaton is its own best algorithm. The only way to find the pattern is to actually compute it step by step. The same reasoning applies to realistic models of CAS.

Figure 9.2: This wolf lichen, Letharia vulpina, grows like a multiply branched tuft or leafless mini-shrub. By Jason Hollinger - Mushroom Observer, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=6051948

different species of algae and fungi into many variants of the symbiotic organism[6,7].

9.3.4 Historical Depth

The state machine model suffers from the same major weakness mentioned in 9.2 regarding Holland's classifier systems. This weakness is to do with the *a priori* limits placed on the individuation of agents and their interactions by the characteristics of their representation. In contrast to the language and terminology used in the first part of the thesis, in the second part we lean towards complementary descriptions given in terms of discrete objects and their interactions and where individuation is depicted in terms of assemblages of elements. Using the terminology developed in chapter 3, these are externalized descriptions characterized by relations being external to the already formed related objects. Originally, CAS were always modelled in terms of immobilized representations and realistically there is almost no escape from that. But for the full picture of CAS as fields of individuation, we need to keep in mind that sufficiently complex agents and situations have an internal mobile continuum – a duration that cannot be rendered in symbolic descriptions without losing something significant, if not critical, of their motion of becoming (see chapters 4-4 and especially 3.4.4).

[6] See Wikipedia article.

[7] The example of lichen is also important because it demonstrates the propagation of heterogeneity in the original populations of algae and fungi to the heterogeneity in the population of the composite organisms.

Interactions must therefore be understood not only in terms of their temporal dimension but also in terms of a historical depth. Historical depth cannot be reduced to a sequence of distinct events of state changes. Also, the response to any perturbation cannot be reduced to a set of discrete operational rules, not even to *a priori* defined continuous functions. Modelling based on continuous dynamic systems may be helpful because they make the problematics involved more apparent. In dynamic systems we become well aware that in many systems certain behaviours (developing trajectories) become ultimately unpredictable because their evolution is infinitely sensitive to their initial conditions (Prigogine and Stengers, 1984, chap 8-9). In such systems, trajectories that are infinitely close at one point in time may diverge radically and unpredictably, which means radically different behaviours. This notwithstanding the fact that at all points the dynamics involved is deterministic. We can understand such phenomena in terms of the system's memory. It can be said that the system possesses infinitely acute memory as to where it came from. Such memory cannot possibly be represented as discrete. Any two discrete points, no matter how close, contain a critical difference of information as to future development. In other words, no boundaries can be placed to distinguish, in such memory, categories, events, episodes etc. It is exactly the kind of memory called above a mobile continuum, or duration, as Bergson termed it. The historical depth of interactions operates as duration – an indivisible record that in many cases critically influences the individuation of agents but cannot be represented by the kinds of models discussed earlier.

To demonstrate a case where historical depth becomes relevant, consider an AI agent of the kind popular nowadays. Suppose it is a neural network trained to perform a complex visual recognition task such as telling whether or not there is a cat in any photo it is presented with. To successfully accomplish such a task, the neural network undergoes a phase of supervised training where a set of labelled example photos (cat present/not present) is presented to it and the weights of connections of the neurons in the network are updated according to the correct or incorrect response of the network to each example. After training with usually a very large and heterogeneous set of examples, the network is capable of correctly recognizing cats in photos it was not exposed to before. The performance of the agent is usually given in terms of how well it is capable of generalizing from the relatively small training set to virtually any possible photo and reliably discover all the cats (and their absence as well). Without entering into the technical details of how it is ensured that training improves the discrimination capability of the agent (see about the back propagation method and deep learning in (Bechtel and Abrahamsen, 2002; Goodfellow, Bengio, and Courville, 2016)), we know that in the course of training, increasing the number of labelled examples incrementally improves the network's performance. Yet no particular example is really critical to the network's final performance. It can be said that the network is taught to recognize a population, not single individuals.

The training algorithms are so constructed that if we train the network with the same set of examples but presented in a different order or with some of the samples replaced with other samples but without changing the overall number of examples, we will get each time a slightly different network. These networks will statistically perform equally well but will err on different specific examples. Even though the whole process of training is entirely deterministic, no structured explanation can be given for the individual differences in performance (i.e., the shortest 'explanation' is reporting the detailed training process). The reason for such differences is the fact that the overall state of the trained network (i.e., the weights of the network), has historical depth. There is no way one can localize how a certain labelled example increases or decreases the probability of correctly recognizing some arbitrary sample from the set of all images. Every sequence of training examples of a given length forms a unique trajectory and though the overall performance is measured as a statistical property of a population of trajectories, the performance of each trajectory in response to certain specific cases is entirely unpredictable. It can be said that the trained agent 'remembers' all the training examples at once and this memory persists as new examples are added. But as a new sample is added all the weights are updated – the whole memory changes. The important fact is that while such AI agents may present very stable statistical properties, certain particular events may produce unpredictable and at times highly disruptive and irreversible behaviour, e.g., my autonomously driving car ran over a cat and no amount of cat recognizing training could absolutely prevent it from happening. But then, the same is true for human agents. Complex cognitive skills individuate with historical depth and their performance in particular cases is therefore not absolutely predictable.

Agents with historical depth affect each other in a manner intrinsic to their historical depth and not only in relation to some discrete structural aspects. This exposes a deeper level of interaction where reciprocal selection actually means the mutual selection of ultimately unique trajectories, thereby producing unique individuated agents with regular behaviours only in the statistical sense, which always leave room for unprecedented and unpredictable surprises. These rare surprise behaviours are one of the marks of realistic CAS.

Understanding the impact of historical depth calls to attention interactive processes that cannot be modelled or simulated, not only in practice but also in principle. These have to do with selecting ultimately singular determinations. Normally, we try to avoid such cases as much as possible and design systems so as to minimize their impact. Yet no design can avoid them completely. Certain individuations remain ultimately unknown until they are determined and the outcome of such determinations has no precedence, computable approximation, or inferential basis. These may be highly disruptive events, coined by Taleb (2008) *black swans* as it was previously believed that black swans did not exist. Yet even here the metaphor is found wanting because real black swan events are not a matter of perception or belief but belong to the unknowable as such.

9.3.5 Signals and Significance

Interactions are not communication, but only an exchange of signals. Signals do indeed carry information in the Shannon sense if one can measure the frequency of their appearance and derive their probability distributions. In this restricted sense the exchange of signals is communication – the communication of change (or difference) without any further designation. Beyond that, signals communicate only if and when they signify something of relevance for the agents that are the source and receiving ends of the signal. Signification arises when signals are contracted into signs. In contraction, or the passive synthesis of differences as discussed in 4.1.2, distinctive points are discerned in the signal and this is how a difference makes a difference for something other than itself (see also 4.2.3.3).

Even then, an exchanged signal may still signify different things for the transmitting and receiving agents. It is not even guaranteed that signs are derived in the same manner in the transmitting and receiving ends. In the extreme case, the signs transmitted by one agent cannot be interpreted at all by the other. This situation is termed *disparateness*. We experience disparateness when we listen to a language entirely foreign to us. Not only are we unable to understand the words but it becomes challenging even to parse sounds and point to when words begin or end. We are able to process the sounds which are the signal carriers of the spoken language but we entirely miss the linguistic signs. If someone were to speak gibberish in that language we could not possibly tell the difference. Disparateness is important because all individuation of signs begins with disparateness. The capacity to acquire signs develops in a process of individuation. In the example of learning a language, certain sound patterns distinguish themselves and are 'contracted' into signs (as explained in 4.1.2). Only in the course of individuation is disparateness resolved and the exchange of signals becomes an exchange of signs. The individuation of linguistic signs is a process of learning with historical depth similar to the one discussed in 9.3.4.

Sense-making – the bringing forth of sense out of non-sense is another name for such a process. When the interactive operations of agents become coordinated exchanges of signs, it can be said that the agents have established a form of communication. All coordination can be traced back to the individuation of communication. Even in the simple case of two people joining forces to push a heavy rock, they do it by exchanging at least one sign: the synchronization of their push. They contract their diverse body movements into a simple distinctive sign pushing/not pushing. It is by exchanging this sign that they successfully coordinate. What becomes significant in this case, is the punctuation of distinctive points – the transitions between non pushing to pushing and the opposite. Notice that communication is still not necessarily linguistic because the signs exchanged need not signify the same meaning for the communicating parties (e.g., in the previous example, if one pushes while the other pulls, the synchronization signs are contracted from completely different body movements).

Complex signal-signs systems are of course nested. In the same manner that the individuation of agents is stratified, so the individuation of communication systems among them undergo stratified development complementary to the development of agents. The signs individuated at a certain stratum become signals in the superstratum concurrently with the agents that exchange these signs/signals. The firing of a neuron in my brain is a sign that certain action potentials in the cell's soma crossed a threshold. The coordinated firing pattern of many neurons is a signal sent to the muscles of my finger to press the full stop key. The keystroke is a sign interpreted by the computer's hardware in a long chain of signals and signs that eventually render certain specific pixels on the computer's screen. These are visual signals that together constitute a full stop sign at the end of this sentence.

The collection of alphanumeric characters constituting the words of this sentence are all signs that project into my retina as visual signals that return to my brain as neuron firings. These are subconsciously contracted into complex word signs as I barely notice separate letters. Discrete words are signals at a yet higher level as they fit together into syntactic configurations and integrate into meaningful semantic expressions. If a sentence is grammatically wrong or incomprehensible, I immediately notice the discrete words, as the higher level assemblage did not cross the threshold of individuation.

This is but a simplified example of a CAS at work. We have neglected the myriad ongoing micro adjustments taking place, from the cellular biochemical level inside neurons, to the hand-eye corrective movements involved in relation to my body position and posture, to the process of composing and understanding a sentence in the presence of hundreds if not thousands of other activations taking place simultaneously, including the thunder storm I hear in the background and fleeting thoughts on tomorrow's plans and what an occasional reader might understand or misunderstand reading this paragraph.

9.4 Cybernetics – The Science of Interaction

Though etymologically the word cybernetics derives from the Greek $\kappa\upsilon\beta\epsilon\rho\nu\eta\tau\eta\zeta$ which means 'governance' and 'steering', cybernetics is first and foremost the science of interaction and communication. It is indeed a historical fact that cybernetics was, more than anything else, associated with control rather than communication but the categorical asymmetry implied by the word 'control' between 'controller' and 'controlled' is misleading and seriously narrows the profound scope of the concept. Some definitions of cybernetics are more subtle, emphasizing the fundamental subject-object, observer-world or agent-environment interrelations but also these tend to assign to one side (the subject, observer or agent) a central part ('controller') and to the other a secondary part ('controlled'). Only a minority of the less mainstream definitions shift interaction to the centre, e.g., Roy Ascott's definition: "The art of interaction in dynamic systems", or, Louis Kauffman's: "The study of systems and processes that interact with themselves and produce themselves from themselves" that emphasize the nature of interaction as presented in 9.1 above[8]. Remarkably, many of the definitions prefer to use the word 'art' rather than 'science'. This tendency does not necessarily indicate vagueness but rather admits the profound complexity of how things in general interact. The broadness of cybernetics reflects the fundamental role of the concept of interaction in all productive processes. Cybernetics exceeds what can be safely designated as scientific in the same sense that thought sans image exceeds symbolic representation.

It was already argued that if there is something rather than nothing (and without presuming the first) it is only on account of interactions. One need not even presume individual agents that interact because even series of differences that enter a relation of reciprocal determination can bring forth regularity, as was already discussed in chapter 4 (especially in 4.2). From this perspective, the most inclusive definition of cybernetics is the science of becoming through interaction, where science here is meant in its older more permissive sense of natural philosophy. It is best positioned on the borderline between open-ended and methodical thinking, where the first is continuously becoming the latter. What follows in this section is a brief survey of a few important cybernetic ideas that did not receive proper attention in the discussion thus far.

9.4.1 Feedback

Feedback is the most basic and straightforward species of interaction. It is best understood in terms of the concept of *variety* developed by Ashby (1957, chap. 7-11). In simple terms variety is the number of distinct behaviours an agent may display, or the number of distinct signals a source of communication can produce (or a recipient of communication can decode). Naturally, variety can be quantified as the informational entropy (measured in bits) associated with the repertoire of behaviours or signals and dependent also on their relative probabilities (see 8.5 for formal definition). For example, a fair coin being flipped can fall on either heads or tails with equal probability and therefore has entropy of one bit. But if the coin is unfair, say with probability of tails 0.1, the entropy (and variety) is much less than one bit (≈ 0.47 bits) because one could guess the outcome of the toss pretty reliably even before flipping it. The variety of behaviours of a certain agent is decreased (or increased) either by changing the actual number of behaviours or by changing their relative probabilities. Changing the number of behaviours is in fact a special case of changing probabilities because reducing the number of behaviours is equivalent to reducing the probability of certain behaviours to appear to zero. Adding behaviours works similarly, by redistributing probabilities over a larger set of behaviours. It is easy to show that the maximum entropy and variety is achieved if all the behaviours or signals in a given repertoire are equiprobable.

[8] See a list of definitions in https://en.wikipedia.org/wiki/Cybernetics.

Consider an agent A with input and output ports A_{in}, A_{out}, and a mapping mechanism A_{mp}. The mapping mechanism dynamically maps input behaviours/signals to output behaviours/signals with possibly a probability distribution that may depend on the input behaviours/signals at A_{in} as well. A_{out}'s variety will obviously depend on both the variety of the behaviours/signals present at A_{in} and the nature of the mapping mechanism. In general, the input and output behaviours of agents do not necessarily correspond. Inputs may trigger changes in the mapping mechanism that determine the output in ways that are otherwise unrelated to the input. For example, imagine a conversation among two or more persons. It is normally the case that what a person is about to say next depends on previous utterances of herself and other participants. Yet certain utterances have special roles in the conversation. Setting the topic of the conversation will constrain the overall variety of what will be said next. Alternatively, an invitation for brainstorming may have the opposite effect of increasing the variety of future utterances. In both cases what was said alters the mapping mechanism in addition to how it influences particular responses to the spoken content.

When a second agent B is fed by A_{out} and in turn feeds A_{in}, we get the basic configuration of interaction (in the redundant case B can also be A itself). A is made to affect itself via the mediation of B and so is B via A. This is what in cybernetics is known as feedback loops. Feedback loops may involve any number of agents and also may be nested (loops within loops). Yet, the important properties of feedback can be demonstrated in the simplest case of two agents or even with a single one connected to itself. Consider in the case of two interacting agents a signal s at A_{in}. The signal will undergo two mapping transformations, first by A_{mp} and then by B_{mp}, before returning to A_{in}. Let the overall transformation of s be $T := A_{mp}B_{mp}$. After one pass along the loop we get sT, after two passes sT^2, and after n passes sT^n. The whole power and significance of feedback lies in the recursive application of transformations. The features of the conjoined transformations in the loop determine the effect of the feedback as a whole.

Let the initial variety of a set of signals S^0 at the input of A be $V(S^0) = V_0$ and the variety after n transformative iterations be: $V(S^n) = V(S^0T^n) = V_n$. If the series V_n converges as in the following two cases, the feedback is defined as a negative feedback:

$$\begin{aligned} &(1) \quad \lim_{n\to\infty} V_n \to 0 \\ &(2) \quad \lim_{n\to\infty} V_n \to V_{constant} < V_0 \end{aligned} \tag{9.1}$$

In both cases the system converges to equilibrium where the behaviour of agents is constrained. In the general case, the system will reach a state where all the signal sets feeding the agents along the loop will each converge to constant variety i.e., constant probability distribution (e.g., recurrent patterns). Though all agents will produce constant variety of signals, not all the produced signal sets will necessarily have the same variety. A special case is where the variety is reduced to zero and the signal at certain or all points along the loop becomes constant. This special case is the one more familiar from simple text book examples.

Importantly, because of the tendency of the whole loop to reduce variety, if a disturbance is introduced anywhere along the loop, i.e., one of the signals is displaced from its equilibrium value (in the special case), or the variety of a set of signals somewhere along the loop increases because of noise, the overall dynamics of the loop will *resist* the change and subsequent transformations will return the system to its equilibrium state (Ashby, 1957, chap. 10-12). Resistance to change is perhaps the most significant feature of negative feedback and forms the most apparent link between interaction and the stability of individuals.

The idea of control is usually associated with negative feedback and especially reaching states of equilibrium. This is because reduction in variety generally means that signals become more predictable and making an agent or a process produce predictable behaviours is the very definition of control (ibid., chap. 10).

If the series V_n diverges, the feedback is defined as a positive feedback:

$$\lim_{n\to\infty} V_n \to \infty \tag{9.2}$$

In positive feedback the variety goes to infinity which means, putting aside practical considerations, that the whole system loses every distinctive property or limit on its behaviour. In other words it loses all individuation and disintegrates into random noise. Practically this never happens. At some point in the process the variety increases enough for some aspect of the organization of the agents, or a function essential to the positive amplification of the whole loop, to be disrupted and the positive feedback simply stops as the variety reaches a finite critical limit. Interaction can either cease to exist, continue with increased but limited variety[9], or transform into different interactive configurations.

In the cases where the variety does not converge to zero and/or disturbances external to the loop are present, interactions may behave in a much more complex manner, which will involve alternation between the negative and positive feedback regimes. These are the behaviours associated with metastability. The series V_n becomes non-monotonous as the variety may both decrease or increase making the behaviour of the whole system more or less individuated respectively. Complex configurations with multiple interactions may display a host of behaviours with combined positive and negative feedback loops and multiple equilibrium points. Notice that the interplay of positive and negative feedback in interactions provides the full range of evolutionary dynamics. While positive feedback provides increased variation, negative feedback provides selection and retention (i.e., resisting change in equilibrium states).

[9]This special case must involve a limiting stabilizing behaviour that implies a switch to negative feedback.

One example that demonstrates the transformative power of interaction and feedback is the case of reinforcement learning (Harmon and Harmon, 1996; Kaelbling, Littman, and Moore, 1996). An agent is given a task which can be very simple or very complex (e.g., winning a game of Go, managing a power grid etc.) to which it responds with an initial variety of behavioural responses attempting to accomplish the task. The process of learning consists of providing the agent with an auxiliary input signal 'rewarding' behaviours more successful in accomplishing the task and 'punishing' behaviours less successful in accomplishing the task. In fact, the reward and punishment signals adjust the probability of outputting the related behaviour in subsequent trials to accomplish the same task. In general, reinforcement is (contrary to what is hinted by the name) a negative feedback because it tends to reduce variety. Yet, it might be the case that the initial repertoire of behaviours, even after filtering out the least successful ones, still performs poorly. One way to overcome such difficulty is by increasing the variety of the repertoire, e.g., producing many variations of the more successful behaviours or even combining their properties to produce novel mixed behaviours. Increasing the variety of behaviours in any performance-dependent manner would consist of a positive feedback. For example, in the case of classifier systems mentioned in 9.2, Holland (2012, chap 6) uses genetic algorithms in order to increase the variety of classifier rules. In summary, a reinforcement learning procedure monitors the gradient of performance of the learning system. It may adjust both the kind and strength of the feedback accordingly. This already involves a second order interaction.

Reinforcement learning need not begin with an externally designed task, as is commonly done. Interacting agents may reinforce or suppress each other's behaviours by providing so called reward and punishment signals to each other. This is a higher level of reciprocal selection. When a population of agents engages in such methodical policy of mutually selecting behaviours by providing reinforcing signals to each other, a market dynamics may emerge where interactions are driven by reward/punishment signals.

9.4.2 Reentry – the Coordination of Interactive Networks

Up to this point we have described the critical role of interactions in productive processes of individuation. In 9.2 we have described CAS – networks of interacting agents – as fields of individuation, and in 9.4.1, we gave a general notion of how interactions facilitate the dynamics of individuation. It is quite clear that interactions, even those that form randomly, have the tendency, under certain conditions, to become persistent by resisting change and limiting difference. These can then become the building blocks of more complex structures.

Most agents, except perhaps the radically simplified agents, can be described as possessing a bias towards engaging in interactions. Be it atoms that combine into more stable configurations or an animal motivated to leave its protected cave, go out and seek food, and once seeking food itself becoming prospective food for others, there can hardly be an action performed without it participating in an interaction. One question that remains though is how interactive networks form. Beginning by assuming diverse populations of agents, in 9.3.1 we already discussed the random formation of simple interactions and how far they might go in breaking the initial symmetry and uniformity of populations. Still, we did not yet get into the finer details of agents acting together. The formation of interactive loops requires not only that agents will be topologically related, i.e., in some relation of effective neighbourhood, sharing a medium or specific transmission channels between them, but also that their reciprocal actions will be somehow coordinated or synchronized without an *a priori* existing coordination mechanism. We hypothesize that heterogeneity and diversity in populations of agents as discussed in 8.1 could provide an answer to both requirements.

First, if a population is heterogeneous enough, agents presenting the same behaviour can be structured very differently and therefore the presence of certain behaviours or signals will not be bound to specific localities within the population. Put otherwise, every neighbourhood of agents within the population will tend to exhibit a wide range of behaviours and every behaviour will be present in almost every neighbourhood. Such uniform topological distribution is favourable in terms of the probability of spontaneous formation of interactions. A similar consideration can be made in regard to temporally coordinating the signals of agents. We may relate to time intervals as temporal neighbourhoods analogous to spatial neighbourhoods. Generally, phenomena have a characteristic spatiotemporal scale in relation to which relevant time intervals can be defined. For interaction to happen, the agents involved must not only meet in space-time but, even prior to that, they must share more or less the same temporal scale (as well as spatial scale)[10]. If each signal present in the population is produced at many different timings, each time interval, given in terms of the relevant time scale, will be populated by myriad instances of the same signal starting at different points along that interval. A diversity of timings permits the reciprocal selection of synchronized signals and behaviours, thus permitting the formation of synchronized interactions with probability correlative to the diversity of timings.

The idea that complex coordinated interactions can initially arise from random connections is inspired by Gerald Edelman's theory of neural Darwinism (Edelman, 1993; Edelman and Gally, 2013). The problem Edelman was addressing is to explain how neural groups connect to form both short and long range circuits that are fully synchronized as to allow synchronized cortical function e.g., the binding of diverse sensory signals into the gestalt of conscious experience, the rigorous coordination of sensory-motor activities and more. Edelman's explanation deployed population thinking and an evolutionary mechanism to account for synchronized neuronal circuits that are also dynamically changing.

[10]The problem of the individuation of scales, only briefly implied in the context of stratification (see 8.3), deserves more attention than allowed by the scope of this work.

Consider two populations of neuron groups. Each population is responsible for producing a specific function. The populations consist of neuronal groups (the agents) performing more or less the same function but producing their output (in the form of firing patterns) with a large diversity of timings. The two populations form between them many connections through which they feed each other with timed signals. These are called reentrant connections. As a result, what appears between the two populations is a very large variety of closed loops that basically manifest the same kind of interaction. Only a minor subset of this large variety of interactions will ever yield useful synchronized activity. The majority of the connected loops will rarely activate and will eventually wither and disconnect because synapses that are rarely activated tend to decay and disconnect. This timing based selective process accounts for the evolutionary aspect of the theory. The remaining minority of connected loops indeed produce synchronized interactions but again at many different timings relative to the timed activity of other neuron populations. These will allow further plasticity in forming interactions with other populations, or dynamically adjusting to variations in timings resulting from the activation of different but overlapping functions within the same interconnected populations. Another way to see it is to notice that while a specific synchronized interaction taking place at a certain moment can cease to be synchronized due to the overall neural activity in one or both of the populations, another interaction of the same kind may just achieve synchronization. From the standpoint of the larger populations, there is an ongoing continuity of synchronization though anatomically the neuronal circuits involved dynamically switch.

The mechanism behind the theory of neural Darwinism relies on populations that provide diversity, a reciprocal selective mechanism (in this case phase locking of neural activation signals), and a retention mechanism (having to do with the preservation of frequently active synapses). We conjecture that a similar but generalized evolutionary mechanism can be responsible for the formation of synchronized interactions in many examples of CAS. At first sight, reentry is not a mechanism that would easily fit into the category of cybernetic feedback mechanisms. But a deeper examination will expose it as a variant of negative feedback. We need only to consider that the above description is identical to a closed chain of processes where each process is not a single unified agent but rather a population of similar agents differing only in their relative timings. The diversity of timings is the variety actually reduced by the interactive activity. It is helpful to keep in mind in this respect that when discussing interactions, agents were didactically presented as unified individuals. In the larger picture each agent is possibly itself a population with diverse properties that undergoes individuation. Of course the role of diversity as described here in the context of synchronization can be applied to other properties of interacting agents.

In summary, reentry provides an additional dimension of freedom (and complexity) in the formation of interactions. Instead of considering the interaction of specific agents that affect and are affected in specific ways, we extend the notion of interaction to interaction between populations. In such cases, the interaction loops are dynamic and particular agents join or leave the actual interaction loops on an ongoing basis while the population level interaction is continuously sustained.

9.4.3 Stigmergy – Mediated Interaction

One cannot fully appreciate the organizing power of interactions without attending to an even less constrained kind of interaction – stigmergic interaction. The concept *stigmergy* was first mentioned in the context entomology by Pierre-Paul Grassé (Theraulaz and Bonabeau, 1999) as a possible mechanism that enables populations of insects of very low cognitive capabilities such as termites to perform what seems to be highly complex projects such as erecting termite cathedrals. The idea of stigmergy is that the actions of agents leave traces (deliberately or not) in the medium where the actions are performed. These traces serve as cues that guide and select the future actions of other agents including the original one. Heylighen (2016) gives a broader definition that does not involve the concept of agent and is reminiscent of Simondon's concept of transduction (see 5.1.3.2):

> "[S]tigmergy is an indirect, mediated mechanism of coordination between actions, in which the trace of an action left on a medium stimulates the performance of a subsequent action."

With stigmergy, complex sequences of actions can be coordinated and organized without *a priori* planning, control or direct interaction or communication among the agents performing the actions. Moreover, stigmergy, in most cases, is agnostic as regards the agent(s) performing the actions. It can perform in the context of populations as well as of small groups of individual agents. As a coordination mechanism, stigmergy is more effective in the sequencing and topological organization (relational locations of activities) of actions. It is less effective in synchronizing actions because in the general case the trace only affects the probabilities of consequent actions. A trace left on the medium, e.g., soil deposited at a certain location by a termite is a cue to other termites to deposit soil nearby or above, following a very simple rule which is within the capacity of the insect to follow. Yet the trace does not specify timing information. Neither does it specify a single action, but only indicates one out of a short list of possibilities. Trails formed by ants between a food source and their nest have a rudimentary time-dependent function: the trail is marked by pheromone traces left by the ants that traverse the trail. The intensity of the traces is proportional to the number of ants passing per time unit. But the traces also evaporate with some half-life constant. If not traversed regularly, the trails fade away and by that manifest a spatiotemporal coordinative function.

The efficacy of stigmergic mechanisms is based on a simple underlying computational paradigm: the medium is a memory. It remembers the history of the actions that happened and from which future actions are induced. The active agents are performing very primitive 'computations' that in most cases amount to 'writing' the memory by leaving traces, and 'reading' from the memory by being triggered to act according to a simple fixed rule(s) corresponding to the trace they just read. The power of stigmergy as a coordination mechanism arises therefore from it being an asynchronous distributed computing paradigm.

The significance of stigmergy lies primarily in the facilitation of complex interactions. Unmediated (direct) interactions require agents to form interactive loops. The probability of incidence of unmediated interactions will decrease and usually quite fast in proportion to increasing the number of involved agents. This might, in many cases, become prohibitive to the emergence of complex interactive networks considering initially only the spontaneous formation of random connections. But this is far from being the case if a population of agents is sharing a medium that allows them to affect each other without ever physically meeting. A trace left by an agent's action is available as a trigger to many other agents of the population, which will then leave their traces on the same medium recursively. Every agent in the population becomes with every action it performs a potential participant in a virtually indefinite number of interactions. The frequency of certain types of traces and their spatial distribution guides the frequency and spatial distribution of subsequent actions. Given a large but finite number of unique traces, a great number of persistent behaviours can emerge in parallel. It seems therefore that the combination of an heterogeneous population and a shared medium is a very powerful yet non-specific catalyst to the formation of interactive loops and to the self-organization of complex patterns. Instead of having a population of agents that need to connect in certain specific ways to form interactions, there is a population of agents and a complementary population of traces that they leave on the medium. Agents from the first population act in parallel and collectively change the distribution of the population of traces. The population of traces, in turn, collectively guides the distribution of subsequent actions that will be performed by the agents.

This description of the stigmergic mechanism highlights the fact that stigmergy is a meta-level interaction between populations – a population of agents and a population of traces. This meta-level interaction is underlied by a third population of specific interactions where each instance is either of the form $Agent \rightarrow Trace \rightarrow Agent'$ or equivalently of the form $Trace \rightarrow Agent \rightarrow Trace'$. The incidence of the specific interactions has a dynamic probability distribution. This population of interactions can be said to be of virtual loops of interaction that make sense only in the context of the whole populations. The particular agents that actually constitute such interactions never connect directly. They only express patterns of activity that can be shown to have a tendency to persist only at the population level. The agents that fleetingly participate in these population-level interactions cannot be possibly identified with them[11]. When the population of agents and the population of traces are themselves viewed as interacting individuals, the way they affect each other is expressed by another individual (or individuating entity): the population of virtual interactive loops just mentioned. This individual is only identified by statistical quantities that are either derived directly from the corresponding population, or inferred from the statistical characteristics of the populations of agents and traces.

The most illustrative example of a complex system of interactions arising in a stigmergic medium is the autopoeitic system of living cells (Maturana, 1975; Maturana and Varela, 1987). Inside the cell's membrane the cytoplasm – the cellular liquid environment – is the medium that hosts a vast number of molecular agents of different kinds. Actions are chemical reactions that leave traces in the cytoplasm in the form of the reactions' products. These, and their relative concentrations (plus molecular agents arriving from outside the cell), trigger further activities. The stigmergic activities going on within a cell give rise to a great variety of interaction networks that bring forth both cellular structures (first and foremost the cell's enclosing membrane) and recurrent behaviours. Interestingly, in the biological mechanisms of the cell, the population of active agents and the population of traces is one and the same. The agents *are* the traces. This example clearly demonstrates the vast potential of mediated interactions to facilitate complex individuations. It seems that CAS are proliferate fields of individuation in large part due to realizing stigmergic mechanisms.

9.5 The Open-Ended Intelligence of CAS

The primary goal of this chapter was to highlight how patterns of structure and behaviour may start individuating via merely contingent interactions without assuming any *a priori* planning, design, guiding principle etc. These bootstrapping processes are especially significant in the context of this work because it is they that facilitate what was termed unsupported thought – the bringing forth of sense out of non-sense. Once populations of stable individuals and behaviours emerge, they become the building blocks of further individuations and of highly complex interactive systems capable (to different degrees) of passively or actively resisting change. The latter case is the definitional mark of adaptive behaviours of CAS. Ashby (1962) in one of his most revealing assertions regarding the power of cybernetic thinking wrote[12]:

[11]In the terminology developed in 8.2, traces and agents are the material aspects of assemblages being formed on the fly, while the actual ongoing interactions are their expressive aspect. Together they bring forth a higher stratum of individuating elements.

[12]On a personal note, it was this quote that inspired me to ask what happens on those 'transients' leading to equilibrium and think about cybernetics beyond the notions of equilibrium and control. Equilibrium is after all a state of forgetfulness where some or all of the initial conditions critical to the becoming of an individual no longer matter to its present and future behaviours or at least so they seem. But this forgetfulness is always an approximation and is mostly apparent in human-designed systems.

> "So the answer to the question: How can we generate intelligence synthetically? is as follows. Take a dynamic system whose laws are unchanging and single-valued, and whose size is so large that after it has gone to an equilibrium that involves only a small fraction of its total states [i.e., the variety remaining after achieving equilibrium], this small fraction is still large enough to allow room for a good deal of change and behavior. Let it go on for a long enough time to get to such an equilibrium. Then examine the equilibrium in detail. You will find that the states or forms now in being are peculiarly able to survive against the changes induced by the laws[13]. Split the equilibrium in two, call one part "organism" and the other part "environment": you will find that this "organism" is peculiarly able to survive against the disturbances from this "environment". The degree of adaptation and complexity that this organism can develop is bounded only by the size of the whole dynamic system and by the time over which it is allowed to progress towards equilibrium. Thus, as I said, every isolated determinate dynamic system will develop organisms that are adapted to their environments. There is thus no difficulty in principle, in developing synthetic organisms as complex or as intelligent as we please."

It is important to note the insightful notion that the structures manifesting in cybernetic interactions become autonomous and in a sense immune to the disturbances produced by the laws driving the constitutive processes going on in lower strata. Individuation processes or systemic cognition indeed bring forth their own laws and regularities. The already formed laws of lower strata cease to be definitional aspects of higher strata. Furthermore, we have discussed already that metastability need not assume *a priori* isolated systems. Therefore, although Ashby requires already formed rules and equilibrium states of isolated systems, as the basis to intelligence these requirements are clearly not foundational. But even under such requirements, Ashby is clear about the unbound degree of complexity and intelligence such systems can demonstrate. Normally, when we think about equilibrium states of systems we have in mind pretty simple examples confined mostly to point attractors and limit cycles, perhaps three dimensional limit cycles but not more than that because higher dimensional configurations are impossible to grasp by the human brain. In real dynamic systems, however, attractor states can exist with very large numbers of variables. The trajectories within such attractors, as noted by Ashby, can indeed become extremely complex. They can easily reflect goal-seeking intelligent behaviours that might be too computationally difficult to realistically simulate or predict. Yet, this complexity is still related to individuated products (i.e., systems that achieved equilibrium) and to intelligence already produced.

[13]This is an extremely insightful notion: the structures manifesting in cybernetic interactions become autonomous and in a sense immune to the disturbances produced by the laws driving processes in lower strata.

What must be emphasized here on top of the above, is the fundamental incompleteness of everything already individuated and thus already given to representation. There is a level of complexity altogether more profound that exists in the becoming of such individual systems. Individuation belongs to a regime of processes that cannot admit either already given rules or final equilibrium states that require closed systems. We believe that we have made the case that the cybernetic rationale behind interactions is powerful enough to account for individuation even without the constraints of isolated systems and fixed rules and without ever achieving global equilibrium.

Most of the effort in this chapter has been invested in demonstrating a plausible yet generalized case of order emerging from non-order via contingent interactions. But even after a CAS has established, through many bottom-up developments, complex networks of interacting individuals, even after adaptive goal-directed agents emerge, contingent and totally unpredictable interactions are and always will be part of the dynamics of further individuations. There is always an unformed pre-individual element intrinsic to even the most organized and sophisticated systems because the chance of a contingent 'black swan' interaction is never zero. Contingency keeps on playing a significant if not a critical role in the bringing forth of the world at all scales. The impermanence of what *is*, is the only *a priori* that we need to admit.

• • •

In the second part of the thesis we have laid out a framework of ideas parallel and complementary to the one presented in the first part but from the perspective of actualization. CAS are actual fields of individuation and as such they are thinking cognitive systems. No matter how rudimentary or complex agents initially are, as long as they engage in interactions, and as long as sizable heterogeneous populations of agents exist, CAS may bring forth novel objects, relations and behaviours. In other words, Ideas in the course of being thought. Though it was already implied by various associations of terms and concepts developed throughout the work, it has not been argued explicitly that CAS are intelligent. They are concretely and actually intelligent but not in the same sense that the concept intelligence is commonly understood. Intelligence is normally associated with purposeful, predictive and adaptive behaviours. More than anything else intelligence is associated with maximizing the performance in achieving given tasks under constraints, the achievement of goals (e.g., maintaining complex equilibrium states) and with problem-solving in general. These intelligent manifestations are already individuated products. The intelligence manifested by CAS, in contrast, is productive. It is neither purposeful nor predictive, at least not globally. It would rather be described as experimental and therefore open-ended.

By open-ended, we mean creative and fundamentally unpredictable in regard to outcomes. Being almost entirely immersed in goal-oriented activity and goal-oriented perception, one can hardly see this intelligence for what it is. Ironically, it is called blind (like natural selection is blind) as if it is merely about random choices of already existing possibilities. But the possibilities being selected are not there prior to the selection; they only seem to have existed in retrospect as if the maximization of some utility function was guiding their selection. The elephant's trunk can be readily explained as having a critical fitness value in the light of all the functions it is observed to serve. But these functions were hardly a leading factor in the evolutionary trajectory of elephants, simply because they did not exist. To argue that the evolution of the elephant's trunk is an outcome of a blind process is not less wrong. The individuation of an organ, a whole organism, a society or a worldview is not about blind selections but rather about *how these come to fit and cohere together in an ongoing interactive process* (Thagard, 2002, chap. 2). Agents brought into interaction in CAS are brought into a problematic situation where each continuously disturbs the others by merely affecting them, causing them to change and consequently disturb other agents. In the course of interaction the agents resolve the problematic situation by reciprocally selecting and progressively coordinating their respective behaviours. This process can initially be based on pure trial and error but gradually becomes (locally) guided as agents learn to associate their actions to disturbances (i.e., cognition) and respond adaptively. They cast a world of significance and become value driven. At all levels and scales of development, from the simplest to the most complex, the motion towards resolution of an ongoing problematic situation is the mark of open-ended intelligence.

Appendix

9.A Description of the program

The program **Test_agents(N,$Samples$)** mentioned in page 205, accepts two input parameters and outputs two histograms and two averages:

N - the number of signals in the population (input).

Samples - the number of random sample of pairs of agents to be computed (input).

Histogram - the distribution of agents in the sample with i distinct recurrent sequences i.e., attractor states (output).

Histogram_seq - the distribution of sequence lengths in the sample (output).

attractors_per_agent - average number of attractor sequences per higher-level agent in the sample (output).

signals_per_sequence - average number of signals per sequence in the sample (output).

9.B Results

Example 1

Number of Signals = 5
Number of possible configurations = 4884375
Sample size = 50000
Sample size percentage of the population = 1.02%
Distribution of agents with i recurrent sequences (attractors):

Attractors	1	2	3	4	5
Agents	32072	15764	2077	87	0

Average attractors per agent = 1.40
Distribution of recurrent sequences with i signals:

Signals	1	2	3	4	5
Sequences	115171	42779	9382	818	14

Average signals per sequence = 1.38

Example 2

Number of Signals = 7
Number of possible configurations = $3.3911e+011$
Sample size = 100000
Sample size percentage of the population = $2.95e-005\%$
Distribution of agents with i recurrent sequences (attractors):

Attractors	1	2	3	4	5	6	7
Agents	55943	36089	7363	582	23	0	0

Average attractors per agent = 1.526
Distribution of recurrent sequences with i signals:

Signals	1	2	3	4	5	6	7
Sequences	278684	127766	44806	9717	1170	65	0

Average signals per sequence = 1.544

Example 3

Number of Signals = 10
Number of possible configurations = $5.0000e + 019$
Sample size = 100000
Sample size percentage of the population = $2.0000e - 015\%$
Distribution of agents with i recurrent sequences (attractors):

Attractors	1	2	3	4	5	6	7	8	9	10
Agents	48251	38973	11080	1588	104	4	0	0	0	0

Average attractors per agent = 1.663
Distribution of recurrent sequences with i signals:

Signals	1	2	3	4	5
Sequences	336182	185388	87103	32113	8464

Signals	6	7	8	9	10
Sequences	1458	183	15	0	0

Average signals per sequence = 1.765

Example 4

Number of Signals = 12
Number of possible configurations = $3.9748e + 025$
Sample size = 100000
Sample size percentage of the population = $2.5158e - 021\%$
Distribution of agents with i recurrent sequences (attractors):

Attractors	1	2	3	4	5	6
Agents	44525	39882	13121	2240	216	16

Attractors	7	8	9	10	11	12
Agents	0	0	0	0	0	0

Average attractors per agent = 1.737
Distribution of recurrent sequences with i signals:

Signals	1	2	3	4	5	6
Sequences	369774	219471	115842	49950	17014	4694

Signals	7	8	9	10	11	12
Sequences	913	131	11	0	0	0

Average signals per sequence = 1.898

9.C Code (written in GNU Octave)

```
## Author: Spaceweaver <Spaceweaver@MIND-ONE>
## Created: 2017-08-17

# Computes an histogram of the number of
#attractors per agent on a sample of random agents
function [Histogram,Histogram_seq] = ...
    Test_Agents(Signals, Samples)
# N is the number of rules
N=Signals;
#number of different agents = number of rule sets
Agents=N^N;
printf('N=%i,Agents=%i,Sample size in (percent)=%d\n',...
                                        N,Agents,100*Samples/Agents);
# Histogram(i) accumulates the number of
#agents with i attractor sequences
Histogram=zeros(1,N);
# Histogram_seq(i) accumulates the number of
#sequences on length i.
Histogram_seq=zeros(1,N);
#create a sample of connected agents and analyze attractors
for s=1:Samples
  #print advancement sign
  #if (s/500-floor(s/500))==0
  # disp(">");
  #endif
  Two_agents=instance(N);
  # Matrix NXN holding the sequences
  sequences=zeros(N);
  sequence_length=zeros(1,N);
  # the number of distinct sequences per configuration
  variety=0;
  # pointers to beginning of next sequence
  Used=zeros(1,N);
  # compute sequences on a single configuration
  current_sequence=1;
  for k=1:N
   if Used(k)==0
      start=k;
      [sequences(current_sequence,:),...
          sequence_length(current_sequence),Used]=...
              find_sequence(Two_agents,start,N,Used);
      Histogram_seq(sequence_length(current_sequence))+=1;
      current_sequence+=1;
    else
      continue;
    endif
  endfor
  #analyze sequences to find only unique instances
  variety = ...
```

```
    analyze_sequence(sequences,sequence_length,current_sequence-1,N);
  #update histogram of agents with distinct sequences
  Histogram(variety)+=1;
 endfor
#compute average number of signals per sequence
signals_per_sequence=sum(Histogram_seq.*[1:N])/sum(Histogram_seq);
printf('Average signals per sequence=%d\n',signals_per_sequence);
#compute average attractors per agent
attractors_per_agent=sum(Histogram.*[1:N])/sum(Histogram);
printf('Average attractors per agent=%d\n',attractors_per_agent);
endfunction


## Author: Spaceweaver <Spaceweaver@MIND-ONE>
## Created: 2017-08-14

#This function produces a configuration of
#two randomely sampled agents.
function two_agents=instance(N)
  two_agents=zeros(2,N);
  for i=1:2
    for j=1:N
      two_agents(i,j)=unidrnd(N);
    endfor
  endfor
endfunction


## Author: Spaceweaver <Spaceweaver@MIND-ONE>
## Created: 2017-08-14

function [sequence,length,Updated_Used] = ...
              find_sequence (Two_agents,start,N,Used)
  vector=zeros(1,2*N);
  sequence=zeros(1,N);
  Updated_Used=Used;
  index=start;
  #Compute sequence
  for i=1:2*N
    vector(i)=Two_agents(1,index);
    #update used entries
    Updated_Used(index)=1;
    index=Two_agents(2,Two_agents(1,index));
  endfor
  #compute length and sequence;
  length=1;
  element=vector(N+1);
  sequence(length)=element;
  for j=N+2:2*N
    if vector(j)==element;
      break;
    else
      length=length+1;
```

```
      sequence(length)=vector(j);
    endif
  endfor
endfunction



## Author: Spaceweaver <Spaceweaver@MIND-ONE>
## Created: 2017-08-17

function [variety] = ...
  analyze_sequence (Sequences, Sequence_length, sequence_number, N)
  workspace=zeros(sequence_number,N+1);
  workvec=zeros(1,sequence_number);
  #find maximal Sequence length
  max_seq_leng=0;
  for l=1:sequence_number
    if Sequence_length(1,l)>max_seq_leng
      max_seq_leng=Sequence_length(1,l);
    else
      continue;
    endif
  endfor
  #sort sequences according to sequence length
  s_index=1;
  for n=1:max_seq_leng
    for i=1:sequence_number
      if Sequence_length(1,i)==n
        workspace(s_index,N+1)=n;
        workspace(s_index,1:n)=Sequences(i,1:n);
        s_index=s_index+1;
      else
        continue;
      endif
    endfor
  endfor
  #eliminate redandancies
  #shift all cycles so the smallest element is first
  for m=1:sequence_number
    if workspace(m,N+1)==1
      continue;
    else
      workspace(m,1:workspace(m,N+1))=...
        shift_min(workspace(m,1:workspace(m,N+1)));
    endif
  endfor
  #compare sequences
  #convert sequences to integers
  for seq=1:sequence_number
    for element=1:workspace(seq,N+1)
      workvec(seq)=...
        workvec(seq)+workspace(seq,element)*10^(element-1);
```

```
    endfor
  endfor
  #sort sequences
  sorted=sort(workvec);
  #printf('sortedvec=%i,%i,%i,%i,%i,%i,%i,%i,%i,%i\n',sorted);
  #compute variety
  variety=1;
  for s=2:sequence_number
    if sorted(s)!=sorted(s-1)
      variety=variety+1;
    endif
  endfor
endfunction


## Author: Spaceweaver <Spaceweaver@MIND-ONE>
## Created: 2017-08-17

function [vector] = shift_min(in_vector)
  len=length(in_vector);
  vector=zeros(1,len);
  #set initial minimal element
  min=in_vector(1);
  #set initial minimal element index
  ind_min=1;
  for i=2:len
    if min > in_vector(i)
      min=in_vector(i);
      ind_min=i;
    else
      continue;
    endif
  endfor
  for j=1:len
    index=ind_min-1+j;
    if index > len
      index= index-len;
    endif
    vector(j)=in_vector(index);
  endfor
endfunction
```

Part III

Articles

Prologue

This part is a rendering of five articles that were composed in conjunction with the materials developed in the first two parts of the thesis and are to be considered as an integral part of this development. Each of the articles highlights a different aspect, approach or application of the major ideas developed thus far. Here is a short description of each:

Complexity and the Philosophy of Becoming - Published in "Foundation of Science" journal in 2015 (Weinbaum, 2015). The article is an earlier development of the topics covered in chapters 3-5, central to which is Deleuze's metaphysical framework. Though there is some considerable overlapping, the system theoretic perspective that the paper takes provides a complementary view on these complex topics and adds a few important clarifications. It also serves as a conceptual bridge between parts I and II. The final publication is available at: https://doi.org/10.1007/s10699-014-9370-2.

Synthetic Cognitive Development - Published in "The European Physical Journal Special Topics" in 2016 (Weinbaum and Veitas, 2017). The article is an earlier development of topics covered mostly in chapters 7-8. It highlights the relations between individuation, cognitive development and sense-making and shows how these concepts can be applied to general systems. The final publication is available at: https://doi.org/10.1140/epjst/e2016-60088-2

Open-Ended Intelligence - Published in "Journal of Experimental & Theoretical Artificial Intelligence"(Weinbaum and Veitas, 2016b). The article develops the concept of open-ended intelligence (see 6.5), and positions it within the wider discourse about Artificial General Intelligence (AGI). A conference paper based on this article (Weinbaum and Veitas, 2016a) was presented at AGI-2016 conference and awarded the "Kurzweil Best AGI Idea Prize" for that year. The final publication is available at:
http://dx.doi.org/10.1080/0952813X.2016.1185748

The Individuation of Social Systems: A Cognitive Framework - Published in "Procedia Computer Science" (Lenartowicz, Weinbaum, and Braathen, 2016a). Based on a longer article (Lenartowicz, Weinbaum, and Braathen, 2016b), this conference article applies the concept of systemic cognition to social systems and shows how social systems can be understood as distributed cognitive systems. The final publication is available at:
https://doi.org/10.1016/j.procs.2016.07.400

Spooky Action at No Distance - Unpublished (Weinbaum, 2016). The article presents an attempt to resolve the EPR paradox in quantum physics (the phenomenon of quantum entanglement) by replacing the underlying metaphysics used to interpret quantum phenomena from one based on individuals to one based on individuation. The article is available at: https://arxiv.org/abs/1604.06775

Chapter 10

Complexity and Becoming

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Complexity and the Philosophy of Becoming

David R. Weinbaum

Published online: 7 September 2014

Abstract This paper introduces Deleuze's philosophy of becoming in a system theoretic framework and proposes an alternative ontological foundation to the study of systems and complex systems in particular. A brief critique of systems theory and the difficulties apparent in it is proposed as an introduction to the discussion. Following is an overview aimed at providing access to the 'big picture' of Deleuze's revolutionary philosophical system with emphasis on a system theoretic approach and terminology. The major concepts of Deleuze's ontology—difference, virtuality, multiplicity, assemblages, quasi-causation, becoming (individuation), intensity and progressive determination are introduced and discussed. Deleuze's work is a radical departure from the dogma of western philosophy that guides the foundations of science and systems theory. It replaces identity with difference and being with becoming; in other words, it provides systems theory with an ontological ground based on change, heterogeneity and the inexhaustible novelty-producing process that underlies all phenomena. The conceptual tools made available by this philosophy seem to capture the fundamental aspects of complexity and complex systems much better than the current conceptual system that is based on static transcendent ontological entities.

Keywords Ontology · Becoming · Complexity · Deleuze · Difference · Individuation

1 Introduction

The subject matter of this paper is the ontological foundations of the study of systems and complexity. Current approaches to complexity already involve significant departures from classical scientific methodologies and their conceptual basis, which go back to Plato, Aristotle and, more recently, the Newtonian worldview (Heylighen et al. 2007). Concepts such as holism (non-reductionist approach), emergence, indeterminism, incompleteness and others

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became the foundations of a general systems theory which provides, as of today, the most effective paradigm in dealing with complexity. We introduce the revolutionary ontology created by philosopher Gilles Deleuze (Smith and Protevi 2008) during the second half of the twentieth century and further adapted to system theoretic terminology by Manuel DeLanda and others. Deleuze's work establishes change (difference) as a primary ontological element, in that it provides a system of thought that naturally addresses dynamic complex phenomena.

Deleuze's ontology of difference arises from his critique of the roots of western dogmatic thinking, where static transcendent essences are foundational while change and difference are secondary and in a profound sense marginal. His ontology offers an alternative not only to the Newtonian worldview but to the deeper understanding of reality rooted in the Platonic and Aristotelian philosophical systems. Central to Deleuze's work in this context are the concepts of difference, multiplicity, virtuality and becoming, which are the primary building blocks of Deleuze's ontology. The application of these concepts requires a departure from the deeply rooted being-based ontology (essence-object) towards an ontology of becoming (difference-process).

This paper aims to stimulate new manners of thinking about complex systems at the conceptual level. Another implicit goal is to establish a cross-disciplinary bridge reaffirming the importance of philosophical discourse to the sciences and of an experimental approach to philosophical problems. The first section proposes a brief critique of the foundations of general systems theory. The critique exposes some major conceptual limitations in dealing with complexity and serves as a background to the work presented here. The following sections give an overview of Deleuze's ontology and detailed descriptions of the most important concepts. The concluding sections discuss possible applications and the overall relevance of the philosophy of becoming to the study of complex systems.

2 A Short Critique of the Conceptual Foundations of Systems Theory

Systems theory has come a long way from classical Newtonian science and indeed represents a major conceptual paradigm shift (Heylighen et al. 2007; Heylighen and Joslyn 2001). However, the theory still suffers from a few serious weaknesses, largely due to its roots in the Platonic and Aristotelian systems of thought and specifically because of its suppositions regarding the nature of reality and the nature of thought. These are briefly outlined below. These weaknesses become more apparent as systems become more complex and their complexity less tame.

2.1 The Transcendent Approach of Systems Theory

In the philosophical tradition, the concept 'transcendence' indicates that which stands outside and beyond existence. The roots of the concept are to be found in religious thought and particularly in the monotheistic Judeo-Christian system. There, it describes the status of God in relation to existence. But the concept of transcendence emerged also as a dominating motif in Greek philosophy and hence became highly influential in western philosophy and the sciences.

In Greek philosophy Platonic forms stand outside human experience and transcend existence itself. The role of the philosopher is to seek to understand the forms which shape the world of matter. Such understanding is achievable via the intellect, which is also considered to transcend the material world. Two kinds of transcendence are therefore apparent: the transcendence of ideal forms to the material world and the transcendence of the human subject to the material world. The idea of transcendence requires a commitment to two ontological substances: one is matter—an inert and featureless substance; the second is mental or ideal—that which gives form and law. The world is created from matter impressed (literally) by form. A second commitment required by the transcendent approach is that the ideal form is superior and more essential than matter. Form subordinates matter under it and the intellect (logos) subordinates the body (May 2005, pp. 27–31).

There are three relevant implications of the paradigm of transcendence:

1. The essential elements of existence are given, unchanging and eternal. Actual forms in the world are only copies of these. There is therefore no ontological foundation to change.
2. The human subject observes the world from a perspective which is outside existence.
3. The method of acquiring knowledge (epistemology) is by extracting the essential forms (ideals and principles) from their lesser material manifestations.

These implications have influenced scientific thought and the way scientific research is carried out. More specifically, in the case of systems theory, one of the important tenets is that structure and function can invariably be abstracted from actual implementation. It is indeed coherent with the idea that matter is an inert featureless substance imprinted with properties, relations and dynamic lawful behaviour whose source is ideal and transcendent to matter itself. From a system theoretic perspective, only those observable abstract properties are significant in a phenomenon. How such properties and behaviours came to be actualized, i.e. the historical, evolutionary aspect of the observed phenomenon, is generally disregarded. Disregarding implementation is perhaps the greatest power of systems theory and is essential to its modelling capacity. In many cases disregarding implementation and history greatly simplifies matters and is indeed practically warranted, yet such disregard lacks a sound ontological foundation. This is not a mere philosophical anecdote as it involves a few difficult problems:

1. A priori given static entities are far from fitting the dynamic and evolutionary nature of complex phenomena and especially the production of novelty (more on this in the following). These ontological building blocks do not account for change and do not give it a proper status. Not having such status means that change is either a secondary phenomenon or perhaps even an epiphenomenon.
2. The transcendent paradigm allows and actually encourages the imposition of representations and presuppositions on reality. By that it often helps to hide (or even entirely replace) the present behind the represented. The combination of points 1 and 2 constitute a bias towards invariance (see also Sect. 2.4 below). The least changing theories and models are considered the most reliable and successful.
3. The position of the observer outside existence and the entailed opposition of subject and object is a profoundly distorted view. Second order cybernetics that integrates the observer into the observed system seems to resolve this issue, yet the resolution is partial at best. The observer is still conceptualized as a unified and coherent agent whose various faculties operate in concert to produce in thought a representation of the present—observed—phenomenon. A phenomenon in turn is similarly a unified coherent source of signs and signals communicating its nature. Observer and observed, subject and object are a priori givens even in cybernetics. Thought as representation and truth as a correspondence between thought and the world are deeply rooted in systems theory and scientific thinking at large (May 2005, pp. 74–81; Deleuze 1994, pp. 129–168). They encompass a philosophical dogma which again understates the dynamic and heterogeneous nature of existence.

2.2 The Black Box Dogma

The black box concept is foundational to how systems are assigned with structure. It is a derivative concept of the transcendent approach which deserves special consideration. A black box is an abstract entity constituted from two abstract distinctions. The first is an arbitrary distinction between an 'inside' and an 'outside' of a phenomenon, or alternatively, between agent (system element) and environment. The second is an arbitrary distinction between 'input' and 'output' which also imposes a transcendent asymmetry in subordinating 'outputs' to be effects and 'inputs' to be causes. While these distinctions are epistemological in nature, pointing towards how one observes a certain phenomenon, they are often regarded as having an unwarranted ontological status, i.e. that inside and outside, input and output are intrinsic to the system and its subcomponents. Moreover, these distinctions are assumed to be mostly invariant, endowing the system with structural stability, which greatly simplifies modelling.

Clearly, black boxes are not intrinsic to actual phenomena. Complex systems are generally open, with indistinct boundaries and even less distinct and stable input and output ports. Additionally, the black box concept highlights the significance of stable organization and abstract relations between components while disregarding possible implementation dependent effects (the happening inside a black box is irrelevant as long as it demonstrates the imposed input/output relations). In real systems, structure might often become ambiguous, inputs and outputs might unpredictably arise or disappear, connections and causal relations might spontaneously form or disengage and inside/outside boundaries shift. Generally, in real systems, there is always more to the parts than what they seem to perform as the components of a larger whole. These facts are unaccounted for by the black box concept.

2.3 The Idea of Cybernetic Control, Utility and Function

The influence of cybernetics on general systems theory cannot be overstated; in many aspects they are synonymous. Two problems are to be considered here: the first is that the cybernetic approach tends to emphasize the significance of stable states and asymptotic behaviour upon the transient and non-equilibrium phases of the evolution of a system (Ashby 1962). The problem is somewhat ameliorated by recognizing the importance of far from equilibrium open-ended processes, but this recognition is not sufficient to cure the paradigmatic weakness caused by this bias. The next subsection examines this problem in the particular context of cognition.

The second problem is that feedback systems are often conceptualized as goal seeking, utility/fitness optimizing and adaptive (homeostatic) processes. Here, again, goals, utility functions and target states are understood as invariant properties of systems or agents in complex adaptive systems. Although it is well understood and accepted that complex systems are staging a theatre of change and transformation, the ontological framework underlying their research programme is still based on fixed identities and final causes.

There is a fine line between describing a feedback system as having a tendency towards certain asymptotic states and describing the same system as having a purposeful behaviour towards achieving a certain goal. As will be discussed later, tendencies can be understood as properties immanent in the system and guiding its evolution. As immanent systemic tendencies they have a clear ontological status and provide local sufficient causes at any point along the developing trajectory within an appropriate state space. Purposeful or intentional description is only a metaphor that cannot merit a similar ontological status. This was already argued by Spinoza at the end of the first chapter of *The Ethics*: "There is no need to show in length, that nature has no particular goal in view, and that final causes are mere human figments" (Spinoza 1997).

Final causation is especially problematic in evolutionary explanations where traits of certain organisms are explained as having been selected to maximize fitness. Such explanation does not explain anything apart from the trivial fact that fitness was achieved by the organism acquiring a certain trait. It does not distinguish the actual solution from an indefinite number of other solutions not less fit that could have been selected but were not selected. What may explain a certain selection in this case is not the final cause of fitness but the predetermined structural constraints of the organism's body plan prior to acquiring that trait. Relative to structural constraints, fitness seems to be the least specifying factor (Maturana and Varela 1998, p. 115).

2.4 Representation and Identity

In *Representation and Change* (1990) Heylighen proposes a concept of adaptive representation that accounts for change via an adaptive feedback process where a representation of a phenomenon is continuously corrected by comparing predictions of the model to actual perceptions. Clearly, developing models with good predictive powers carries with it significant evolutionary advantages. While the idea of adaptive representation attempts to resolve the problem of dealing with the fundamental dynamic nature of existence, it actually exposes a deeper problem: the very feedback mechanism that builds representations of a state of affairs external to the organism is a process that by definition stabilizes identities (i.e. representing objects through invariant properties). These cognitive mechanisms seem to have evolved to predict future events based on past experience. As such, they are optimized to discover and extract invariants in the stream of sense data (Hawkins 2004). Similarly, in the general process of scientific observation the focus is always on the discovery and highlighting of invariant laws that *explain away* change or contain it. We always seek a representation that will subsume change under an invariant principle. In other words, we understand and explain the world by eliminating change and affirming a stable existence. This paradigm seems to have deep evolutionary roots but it fails to address and properly account for the majority of complex phenomena where change cannot be reduced to regular patterns and subsumed under invariant representations. Dealing with change seems to require a paradigm that goes beyond representation altogether.

We can now start to appreciate the difficulty invoked by the essences and fixed identities ingrained in systems theory's conceptual framework. These concepts seem to be categorically incompatible with any attempt to allow change an ontological status. An explanatory method based on identities as its ontological elements fails to explain the transformation of one identity into another. Deleuze's approach suggests a radical alternative: he gives up altogether the ontology of given, fully formed individuals (identities, beings, agents, states) and instead he adopts an ontology that accounts for the genesis of individuals via *a process of becoming* e.g. the developmental processes that turn fertilized eggs into embryos and embryos into organisms, or, the evolutionary processes of speciation. Deleuze's ontology, as we shall see, accounts for the objective production and evolution of spatio-temporal structures and boundaries of individuals. In doing this, Deleuze introduces a novel conceptual framework that overcomes the shortcomings of systems theory just described. This is especially important in the context of complex systems, where these shortcomings turn out to be critical.

3 An Overview of Deleuze's Ontology

Deleuze's philosophical programme in *Difference and Repetition* is ambitious. It was his intention to overthrow the hegemony of the Greek philosophical paradigm and much of what evolved from it in human thought.[1] He criticized this paradigm as dogmatic, rigid and based on unwarranted axiomatic presumptions that shaped what he called "the image of thought" (Deleuze 1994, pp. 129–168). His ontology is an attempt to replace it with a novel experimental philosophical paradigm, which he calls transcendental empiricism (Deleuze 1994, pp. 143–148; Bryant 2008). A philosopher's work, according to Deleuze, is inventing new concepts with primary attention to the significance and relevance of these concepts in relating to real world problems and not necessarily to their truth. Trial and error, tinkering and speculation are necessary tools in a philosopher's toolbox, according to Deleuze.[2]

To understand Deleuze's novel philosophical system we can start from DeLanda's description of Deleuze's position as a realist, i.e. granting the whole of existence an observer independent status (DeLanda 2005, p. 2). But this would be only a gross approximation. Deleuze's experimental approach finds its most profound application in the very way he constructs his position. Following Hume he would accept that all sense making (and consequent knowledge) must derive from sense experience. But in distinction to Hume's empiricism he further questions the presuppositions made by the empiricist position, namely, the subject of experience. The subject, according to Deleuze, could not be 'a given' in the empiricist position; he must be somehow constituted in the course of sense making (Moore 2012, pp. 551–553). Transcendental empiricism is a paradoxical construction as it alludes to two opposing positions: Hume's empiricism on the one hand, and Kantian transcendental categories on the other. The Kantian position necessitates a transcendental subject in possession of transcendental categories (such as space and time) antecedent to the given in experience in order to make sense of experience. "Are there universal conditions for appearances in thought and sensation?" (William 2012, pp. 33–54). According to Hume's empiricism the answer is no. According to Kant's critique of Hume the answer is yes. Deleuze's position tries to avoid these oppositions and to affirm both. To accomplish this he redefines both.

Deleuze's transcendental empiricism does not try to answer how objects or subjects produce one another. It starts with a position where neither is assumed a priori and examines how both subjects and objects can be produced out of a field that does not assume either. This field is a field of differences, also termed by Deleuze the 'plane of immanence' or the 'virtual plane' (Bryant 2008, p. 265). At the beginning of Chapter 5 of *Difference and Repetition* he writes:

> Difference is not diversity. Diversity is given, but difference is that by which the given is given, that by which the given is given as diverse. […] Every diversity and every change refers to a difference which is its sufficient reason. Everything which happens and everything which appears is correlated with orders of differences. (p. 222)

The concept of difference, as we will see, is the key to Deleuze's transcendental empiricism. Difference is transcendental in the sense that it is that by which the given is given. Nothing needs to be presupposed beyond difference. But difference is different per encounter. It is not a unifying universal principle or dogma that precedes all sense making and sense makers.

[1] In his critique on the foundations of western philosophy Deleuze is following Nietzsche. See for example: Bell (2006, pp. 63–113) and Deleuze (2006).

[2] This revolutionary approach causes more than a slight discomfort to many orthodox analytical philosophers that often describe Deleuze's work as obscure, inconsistent and highly speculative.

Therefore it is a singular event or encounter by which both subject and knowledge are constructed; hence Deleuze's deeper sense of empiricism. Closing the circle one can indeed see Deleuze's position as realism, but it is a novel kind of realism where no formal essence is presupposed. The real is a continuous process of being born out of difference, i.e. becoming.

Deleuze establishes his position by constructing an elaborate ontological programme that can be summarised in the following four points:

1. Immanent properties replace transcendent impositions.
2. Difference replaces identity as the most fundamental ontological element.
3. Multiplicities replace essences and ideas.
4. Becoming (individuation) replaces being[3] (given a priori beings).

The combination of these four points constitutes a novel ontological system that rejects the transcendent ideal ontology of both Plato's and Aristotle's typological categories.[4] If ideal and typological essences are rejected as ontological elements, what grants existence? To answer this question, Deleuze applies a new approach to Spinoza's concept of substance. In his unique style of addressing and reformulating the works of other philosophers, he radically reshapes the concept, yet keeping it faithful enough to Spinoza's idea in at least two important senses: univocity and immanence (May 2005, pp. 32–39).

Univocity is the technical term for the ontological equivalence of all expressions of substance. In simple terms it means that substance is one, indivisible and has no types and levels. Additionally, it means that the diversity of expressions does not reflect diversity of senses or manners in which substance expresses.

In Spinoza's concept of substance, substance always retains its identity as the ultimate oneness in all its attributes and modes. But Deleuze follows Nietzsche and goes beyond essential identity by showing how the univocity of substance can be understood in terms of difference (that which differs or is modified), that is, all being is the being of difference, of becoming and of endless novelty (Moore 2012, p. 549). Deleuze's substance, in distinction to Spinoza's, is pure change, infinitely and inexhaustibly expressive and productive—ever producing myriad different expressions *of itself in itself*. The modes, the modifications of substance, take priority in Deleuze's recasting of the concept, as substance is none but its expressions. This is exactly what immanence comes to mean in Deleuze's modification[5]: *substance cannot be considered apart or separate from its myriad expressions*. Therefore substance *is not* a unitary entity unifying all its expressions. It is not transcendent to the existence of any of its expressions and is not presupposed to existence. Deleuze's substance is a pure multiplicity, a 'many' without a 'one' that precedes it, unifies it or contrasts it.

Substance therefore grants existence but it does not grant any constant expression to existence. In its expressions, it does not bring forth any universal pattern or principle. Existence instead is a (process of) becoming—a continuum of pure changes (Williams 2003, pp. 63–69). Expressions of substance are the whole of reality.

Physical phenomena are only one class of such expressions of substance. Biological tissues, populations of organisms, ecologies, societies and financial markets are all examples of

[3] The contrast between becoming and being can be traced back to the influential works of Heraclitus and Parmenides, but it is only in the work of philosophers such as Nietzsche, Bergson and prominently in Deleuze's that becoming regains primacy.

[4] Typological categories bestow ontological status on generalizations through the concept of species.

[5] The term modification is used here to emphasize that Deleuze's novel conceptualization of substance does not contradict, negate or oppose Spinoza's concept. Deleuze rather introduces a difference, a novelty and by that he reaffirms Spinoza's concept, as all affirmations are repetitions and every repetition is a repetition of a difference.

individual expressions of substance that are not necessarily mediated by or reducible to physical properties. Expressions of substance are termed multiplicities, where each multiplicity is a pattern of becoming that gives rise to actual phenomena associated with it. All multiplicities are laid out and meshed on what Deleuze calls ‘a plane of immanence’ or ‘plane of consistency’ (Deleuze and Guttari 2005, p. 9). The ‘plane’ is one of Deleuze’s most fundamental concepts. It carries no resemblance to a geometrical plane; it is rather the continuum of all multiplicities—the different expressions of substance. It is a plane because these expressions are univocal, i.e. ontologically equivalent. The ‘plane of immanence’ is not an abstraction but a concrete morphogenetic field (see following) that guides the dynamic constitution of actual phenomena (i.e. its individuation). Reality thus constituted is ultimately complex, dynamic and interconnected.

Three ontological dimensions constitute reality (existence) according to Deleuze: these are the actual, the intensive and the virtual dimensions. Each of these is populated by specific concrete elements. The actual is the ‘surface’ dimension populated by fully individuated phenomena with observable qualities and measurable spatio-temporal extensities. The virtual is the ‘depth’ dimension populated by multiplicities (as will be clarified in the following sections) that are spaces of pure becoming. The virtual is always disguised under the appearance of the actual and contains the patterns of becoming (morphogenetic patterns) that govern the individuation of all actualities. These patterns exist, as we will see, as independent from any *specific* material implementation, yet they are immanent in phenomena and cannot be said to exist independently of any expression at all. The virtual is the realm of infinite embryonic[6] expressions. It is the aforementioned ‘plane of immanence’; no individuated phenomena and no individuating processes are taking place in the virtual; it is causally sterile. Yet, the virtual is not static. On the virtual plane, pure change (as difference) is laid out prior even to time and space or any other quantifiable or qualifiable actuation. If the actual is the ‘external’ overt aspect of reality, the virtual is the ‘internal’ and disguised aspect of reality.

The intensive dimension is the mediating dimension between the virtual and the actual, though it cannot be thought of as separate from either. The intensive dimension is mostly disguised by the actual as well and is populated by productive individuating (morphogenetic) processes guided by virtual patterns and producing actual phenomena. Intensive processes are processes that are driven by differences in intensive properties.[7]

Intensive properties are those properties of matter that are not divisible, in contrast to extensive properties like volume, area, mass, electric charge etc., which are divisible. The most obvious examples of intensive properties are temperature, pressure, velocity, chemical concentration etc. Differences in intensive properties, or, in short, intensive differences, tend to equalize by driving fluxes of matter and energy. The most obvious example is how differences in temperature and pressure drive weather systems, or how temperature gradients in viscous liquids drive convection processes. Intensive properties are not necessarily thermodynamic in nature, however. The concept can be extended to include other properties that are appropriate to various expressions of substance. For example: differences in scarcity or abundance of a resource can drive economic processes; differences in distributions of predators and prey within food chains can drive ecological and evolutionary processes; differences of demographic distributions within a population can drive social processes; genetic differences within populations can drive phenotypic adaptation processes, and so on. All these can be

[6] Embryonic is used here to make clear that the virtual is not populated by possible or potential existences that are fully formed and just need to be ‘realized’. Embryonic comes to mean a not yet formed expression. Yet even this metaphor captures only approximately the meaning of a virtual expression.

[7] Deleuze’s theory of individuation is greatly influenced by Gilbert Simondon’s work. See Simondon and Garelli (1995), Simondon (1992, 2009).

considered intensive differences which are not thermodynamic, at least not in any obvious sense.

Intensive differences drive processes of actual change. Processes of change are driven by intensities and governed by the virtual patterns immanent in them, reflecting their intrinsic tendencies. For example: a system with a tendency towards equilibrium states will tend, at least in part, to cancel intensities and produce asymptotically stable phenomena or regulated periodic changes (the cycle of seasons in the global weather system) that disguise the underlying intensive processes or cancel them altogether. Systems that tend towards far from equilibrium dynamics will, in contrast, produce less tame kinds of phenomena and expose an actual intensive process. This is where complexity is observable.

Intensive processes are called individuating because they specify unique actual phenomena and give *rise to individuated identities as effects* (products) of processes. For example: physical, ecological and social systems may share the same immanent pattern of becoming (in the virtual dimension), yet each undergoes a unique process of becoming giving rise to phenomenal products which do not have any actual resemblance to each other. Individuated identities stand in contrast to the elementary status of identities in the Platonic and Aristotelian systems.

In the ontological investigation of an actual phenomenon, we start by identifying the individuating intensive process that produces the phenomenon. We go from the product to the productive. We are then in a position to study this process and extract from it those patterns of becoming which are immanent in it but independent from its specific (individual) properties and structure. By that, we can uncover the virtual aspect of the phenomenon in the form of a multiplicity that guides the process. The patterns that constitute the multiplicity expose a completely hidden aspect of actuality. They may, for example, indicate tendencies and capacities that were never actualized but nevertheless are immanent in the system. In this sense, the virtual aspect of a phenomenon is its concrete (and inexhaustible) potential of becoming—a source of indefinite novelty that goes beyond any specific individuation process and any specific actual product. Deleuze assigns to multiplicities a status of 'concrete universals', and develops an empiricism of the virtual that complements the empiricism of the actual. While the empiricism of the actual is concerned with distinct identities, the empiricism of the virtual is concerned with the complex connections and the as yet unformed embryonic expressions hidden in every distinct phenomenon. Here Deleuze repeats and reaffirms Spinoza's assertion: "We do not know what a body is capable of" (Deleuze 1988, p. 17).

This draws, in a nutshell, the big picture of reality according to Deleuze. In the following sections this picture will be clarified as the details fall into place.

4 The Virtual

The virtual is the most fundamental and philosophically novel among the three ontological dimensions that constitute Deleuze's ontology. To grasp the concept of the virtual, it is best to follow the points of the Deleuzian programme and see how the virtual is carefully constructed to implement this programme.

Deleuze's reality is populated by individuals (and as we will see assemblages of interconnected individuals) but following Simondon (see footnote 7), he rather speaks of *individuations* i.e. individuals as processes and not as finally formed fixed identities. Those aspects of individuals that are determined and therefore identifiable belong to the actual dimension of reality while those aspects that are not (as yet, if ever) determined belong to the virtual dimension of reality. The virtual and actual dimensions of reality form a continuum. Virtual elements are called virtual because they are *determinable but never fully determined*. Virtual elements are distinct from actual elements in that they do not possess a determinate identity.

The virtual dimension describes the intrinsic nature of existence without resorting to anything transcendent or essential. It characterizes a universe of becoming without being in which both objects and subjects are never presupposed but constructed through individuation processes. In such a universe there is nothing essential to individuals and they possess no fixed identity. Individuals (actual individuated phenomena) are effects, outcomes and expressions of a dynamic substance—a pure becoming.

Virtual elements, therefore, are not objects or temporal events per se, but rather exist in a state of *pure becoming* i.e. determinable but not yet determined. In the common manner of thinking, actual objects or temporal events are determined by their essential properties or the ideal essences they reflect. Properties and essences are the basis of identifying, categorizing and comparing between objects. In contrast, according to the Deleuzian ontology, actual objects are determined by their history of individuation, or, in other words, by the irreversible process of becoming by which their character is progressively determined.

Since the actuality of every object is necessarily complemented by its intrinsic intensive and virtual aspects, no actuality is entirely and finally determined. Underneath every actual appearance there are always active individuating forces (i.e. intensities), shaped by immanent virtual tendencies that constitute an open-ended potentiality for variation. The metaphor that describes becoming best is embryogenesis, where progressive phases bring about the differentiation, discrimination and individuation of parts and qualities of the system, which in antecedent phases are more or less fused and indistinct.

Difference is the primary ontological element of the virtual. As we will see in the next section, Deleuze constructs a novel concept of difference. It is this element that stands at the foundation of his ontology. One might immediately wonder—difference between what and what? It was the ingenuity of Deleuze to recognize the conceptual trap embodied by this question, which already presupposes prior determined identities, and devise a concept of difference that avoids it altogether.

The structure of the virtual is given by the second most important ontological element, which is multiplicity. A multiplicity is how differences relate to each other and become affective in the individuating processes of becoming, or as we will see, how they enter into relations of reciprocally determining each other. As was mentioned before, all multiplicities are meshed into a continuum—the plane of immanence which is the virtual in its entirety.

Difference and multiplicity are the subjects of the following sections.

5 Difference

In the Aristotelian ontological system, which deeply influences the way we think, difference pertains to how we discriminate between beings and essences. Aristotle's principle of non-contradiction states, "The same attribute cannot at the same time belong and not belong to the same subject and in the same respect." This axiomatic principle ensures that objects cannot differ from themselves and is therefore a principle of (numerical) identity. Once we establish the identity of X by specifying all its essential properties, we can, from then on, establish for any X′ whether it is identical (X′ is X), similar (X′ and X are identical in concept but can differ in some non-essential properties) or different (X′ and X are different in concept, i.e. in at least one essential property). There exists also a radical difference where X and X′ do not share any essential property and are said therefore to be opposites. It is also important to note that within this understanding of difference, if X is different from X′ it necessarily follows that X′ is different from X. In other words, difference is a symmetric relation. A symmetric relation of difference is what conventionally makes two things distinct from each other.

In all these, difference is secondary to identity in that it must rely on and derive from identity. When we try to understand what difference is according to the Aristotelian dogma, it is readily apparent that difference is not only secondary but has no concept at all and describes only a modification of identity. It is definitely of concern that difference, which plays a major part in our understanding of life, evolution and cognition, lacks a clear concept, only filling the gaps, so to speak, between a priori given identities.

The problematic nature of difference and especially that it lacks a clear concept, is central to Deleuze's work. As a foundation to his philosophical programme aiming to replace the Aristotelian system, Deleuze proposes a revolutionary theory of difference: instead of identity having the primary ontological status and difference only a secondary status subordinated to and deriving from identity, Deleuze makes difference the primary ontological element and identity secondary to it. He rightfully describes his attempt as a Copernican revolution in philosophy (Deleuze 1994, p. 40). His theory establishes a concept of difference which is *independent of the concept of identity*. This new concept of difference is necessary to the understanding of the virtual.

What is difference according to Deleuze? It is:

> … the state in which one can speak of *determination as such* (my italics). The difference 'between' two things is only empirical, and the corresponding determinations are only extrinsic. However, instead of something distinguished from something else, imagine something which distinguishes itself—and yet that from which it distinguishes itself does not distinguish itself from it. (Deleuze 1994, p. 28)

In yet more concise form: "Difference is this state in which determination takes the form of unilateral distinction." (ibid.)

The Aristotelian symmetric difference that can only exist between two determined identities is replaced by a unilateral relation: X′ can be different from X, while X is still indistinct from X′. This seemingly 'cosmetic' modification carries with it immense consequences. We can now describe situations where X′ is *becoming distinct* from X yet *not entirely distinct* from it (because the symmetry of the difference is not achieved). If X′ is a difference relative to X, it still does not gain an independent identity, because it cannot be said to be fully distinct from what it distinguishes itself from. This new ontological object, in all its simplicity, is the very tool by which identity-based existence is upturned. Substance as difference in Deleuze's ontology explains how substance modifies itself in expression without ever becoming entirely distinct and separated. All the expressions that constitute existence are series of differences and differences of differences recursively to an indefinite order. All is difference yet all is connected—a unity in multiplicity. No substance therefore is distinct from the differences which are its expressions. There is no 'original oneness' in existence, only an ever-differentiating variety which is multiplicity without a 'one' to contrast it. To describe difference, Deleuze is using metaphors such as 'larval' and 'embryonic' to emphasize the new ontological status of a partially formed identity, or, a pure becoming. Additionally, since there are no final and complete distinctions, all differences form a continuum—the virtual plane of immanence.

Differences as indeterminate identities have characteristics which initially seem counter intuitive to conventional thinking. An element X can become a source of a series of consecutive differences (X′, X″, X‴…). Since X persists (immanent) in X′ and all the differences that arise from it, in a sense X can be said to differ from itself through the differential elements that become unilaterally distinct from it. From a parallel perspective, the series of differences (X', X'', X'''…) can be said to constitute the intrinsic depth of X. Intrinsic depth means the inexhaustible number of manners in which X is different from itself *in itself*. This is also the inexhaustible manner by which the partially determinate identity of X could be further determined and become more distinct (but never completely distinct). These simultaneous parallel perspectives where X is intrinsic to anything unfolding from it while any unfolding of X is also found as its intrinsic depth, is unique to all individual elements in existence. While the actual is the surface of individuated existences, the virtual comprises their depth.

Although it will not be discussed here in the length it deserves, in the mathematical sense differences are topological in nature and not metric. This is intuitively apparent since there is no way to define a proper distance function between two elements that possess only partial identity. In a series of unfolding differential elements such as (X, X', X'', X''',…), the elements hold between them only ordinal relation and possibly ordinal distance.[8] Each element is distinctly positioned only in relation to the previous one and the one following it. There are no privileged elements in the virtual. There are no 'original' elements; there is no hierarchy of similarities or proximities to an original object. All these stand in contrast to the common notion of actual (extrinsic) difference as something that can be quantified or qualified. Pure differences—the elements of the virtual, cannot (DeLanda 2005, p. 74).

To gain a deeper understanding of the nature of virtual differences let us consider a piece of metal which is heated to a degree where it becomes bright red. Suppose that we have a scale of brightness where X, X', X''… are the degrees of brightness at different consecutive time instants T, T', T''. In the conventional way of thinking we relate to the piece of metal at different instants as essentially the same entity undergoing changes in one of its non-essential properties. In the Deleuzian way of thinking the sameness of the piece of metal is only superficial. Every instant is a distinct instance[9] (individuation) of a piece of metal. As we observe the piece of metal at an instant T, we can make note of its actual brightness X. The specific degree of brightness we observe did not appear out of nowhere, however. It could be that the piece of metal was less bright an instant before and will become brighter an instant later. Alternatively, it could be brighter an instant before and become less bright an instant later. It could also be that the piece of metal was less bright or brighter both an instant before and an instant later (X is a maxima or minima of brightness respectively). Finally, the degree of brightness could be unchanged, but this case is more difficult since we always need some discernible change to make the distinction between consecutive instants. If we have only the piece of metal and its brightness to judge by (and assuming everything else equal), as long as the brightness is constant we necessarily remain at the same instant.[10]

All these trajectories of changing brightness pass through the point (T, X). Each trajectory is unique in how differences in brightness may develop around (T, X). Remarkably, we cannot know just by observing X at T alone on which trajectory we are. To use the new

8 Ordinal distances measure the degree of dissimilarity between differential elements. They can be compared but a difference between ordinal distances cannot be cancelled because they are not quantifiable measures. For example one can know that A is more different from B than C is from D, but there is no meaning to ask how much it is more different. This becomes important when two series of differences are related via a third series of differences, which is the manner by which differences connect on the virtual plane to form a continuum.

9 The word 'instance' is used here to signify something akin to an instantiation of a variable. An instance is any product of determination but not necessarily fully determined. Yet every instance is unique.

10 This has implications for the very understanding of time and its relation to change.

understanding of difference, X is the actual (empirically observable) situation of the piece of metal at T (of course this actual situation involves other variables that are omitted here for the sake of simplicity). The trajectories that pass through (T, X) and in a manner of speaking are hidden by (T, X) and only 'hinted' by it, are together the pure becoming of the situation determined by (T, X). There are an infinite number of such trajectories, each with its unique speeds of rising or falling brightness.[11] This pure becoming is indeed determinable but not determined. It is determinable because a continuous observation along a few instants will show that necessarily one of the trajectories will have eventually *become* the actual one. It is not yet determined because the actual empirically measured brightness X at T does not select any one of the trajectories independently of anything else (i.e. without additional information inferred from other observations). Yet, not everything goes either; all the said trajectories are already partly determined by sharing the actual point of brightness X at instant T.

The set of these trajectories of potential change (in brightness) constitutes the virtual difference immanent to the piece of metal at instant T. Both the actual and virtual dimensions are real. If we take the piece of metal as an individual, or rather as a process of individuation, we can clearly see how its virtual dimension is the space of its becoming and how the partial identity of the piece of metal develops without ever losing either its actual aspect or its virtual one.[12] Furthermore, any actual (empirical) difference observed in the piece of metal at instant T can be said to be a product of a determination of a virtual difference. We can also see how a virtual (not yet determined) difference in brightness is a unilateral difference, as described above. It is a difference that distinguishes itself from the actual instance of the piece of metal in the form of myriad potential trajectories. The actual instance, in turn, encompasses (and hides) the virtual difference immanent in it in a manner that leaves it indistinguishable from them because nothing at instant T further differentiates trajectories. Finally, we can see the ultimate individuality of the piece of metal at any instant and why its observed continuous identity is only a superficial effect. Certain trajectories that pass through (T, X) may involve differences which are so extreme that the very shape and other associated properties of the piece of metal may change violently (e.g. from gas to solid and back to gas) while passing through (T, X). The continuity of identity we observe is therefore only an effect of the specific trajectories being determined in the piece's process of individuation.

This example, however, is a great simplification as we involved in it only a single variable property—brightness. But the piece of metal while changing its brightness is simultaneously changing in many other ways as well, e.g. its temperature, its electric conductance, etc. Also, of course, its shape and mechanical properties may change, either in correlation to its brightness or independently of it. As noted above, at the extremes of such change, the piece of metal may turn to liquid or even gas, become mixed with other substances and lose its individuality as a piece of metal altogether. Such events involve a much more complex picture of the virtual dimension. In order to gain clarity of this picture we turn now to the concept of multiplicity. The following section describes how differences are related and organized into multiplicities, that is, structured continuums of multiple virtual differences. Multiplicities present intricate systems of relations among differences and by that constitute the structure of the virtual dimension.

[11] We will later see that these trajectories constitute a multiplicity.

[12] In Sect. 6.2 we will see that certain differences are more significant than others and are therefore called singularities or virtual events. They are important because they are 'turning points' in the process of becoming that bring forth actualizations and therefore have a distinct signature on both virtual topography and actual outcomes.

6 Multiplicity

6.1 Multiplicities in a System Theoretic Framework

In describing the concept multiplicity in the context of systems and with the aim of making it accessible to scientifically oriented thought, this paper follows DeLanda's reconstruction of Deleuze's work (DeLanda 2005, p. 14). Notably, however, Deleuze's development of the concept multiplicity is primarily metaphysical, even if he appeals in many places to mathematical terminology (Williams 2003, pp. 143–146). The use of mathematical and system theoretic terminology here should therefore be regarded as an attempt to bridge between disciplines of description: metaphysics on the one hand and system theoretic thinking on the other. As such, it understandably avoids certain important nuances but exposes enough to stimulate a novel approach in system theoretic thinking.

6.1.1 State Spaces

Following the history of dynamic systems science, DeLanda argues that much of what constitutes multiplicity can be derived from mathematical methods that were developed to model dynamic systems, primary to which is of course the idea of state space (Abraham and Shaw 1992, pp. 13–47). Briefly, a state space is a multidimensional space whose dimensions are the various parameters that fully describe the state of a dynamic system. Every point in the geometrical representation of a state space represents the state of a system at a given moment in time. Continuous sequences of such points form trajectories. A trajectory is a sequence of successive states of the system that describes the dynamic development of the system between two instances. The shape of trajectories reflects the mathematical relations held between state variables that in turn describe the development of state dynamics. Trajectories, therefore, express geometrically the lawful dynamics of the system. Additionally, neighbouring trajectories generally have a similar characteristic shape that sooner or later converges into well-defined subspaces (basins) of the state space, called attractors.

Metaphorically speaking, the physical properties and dependencies of the parameters that describe the system are encoded into a topography of the state space. The trajectories, which are distinct dynamic developments of the system, are bound to follow the topographical shape of the state space. In the classic view of dynamics, the actual trajectory of a system is determined by a combination of the state space topography and the initial starting point—encoding the initial state of the system and determining which of the infinite distinct trajectories will trace the actual dynamics of the system.[13]

Further development of system dynamics was the discovery of attractors. Attractors are special points, curves and surfaces of any number of dimensions and of a specific geometrical shape that characterize the topography of state spaces. These are called attractors or singularities because they seem to influence the shape of the trajectories in their vicinity, bounding them into distinct classes of shapes. These classes correspond in turn to classes of dynamic behaviours of systems, for example: the converging into fixed stable states, simple periodic oscillations, or other more or less complex recurrent patterns.

Interestingly, various configurations of attractors were discovered to be recurrent in diverse physical systems. These systems sharing more or less the same topography behave dynamically in exactly the same characteristic manner even though their actual physical manifestation

[13] Initial point or initial condition of a system is a practical and arbitrary imposition made by an external observer. A dynamic system does not have privileged initial conditions of any kind. An initial condition marks only the state of the system when observation began.

is radically different from one system to another. At the end of the nineteenth century and during the twentieth century it became evident that different systems share generic characteristics of their state space topography (technically termed phase portrait). Such generic characteristics are independent from any specific implementation. The behaviour of such systems follows, therefore, dynamic patterns which are independent from their specific physical construct and depend only on their shared state space topography (DeLanda 2005, pp. 182–183; Abraham and Shaw 1992, pp. 349–360).

6.1.2 State Space's Topological Nature

Another development important to the understanding of the concept multiplicity took place with the advent of complex dynamics and chaos theory towards the second half of the twentieth century. This development has to do with the structural stability of state space topographies. Many systems happen to display a complex dynamic behaviour that is expressed not only by following trajectories within their state space, but also by the state space's topography becoming sensitive to certain systemic variables. Depending on such variables, the state space topography transforms: valleys can turn into mountains, ridges can appear or disappear, gentle slopes can turn into steep ragged areas and so forth. State spaces have, therefore, a characteristic structural variability that describes how their overall topography changes in response to perturbations in certain systemic parameters. Structural variability of state spaces necessarily requires that in the most general case state spaces are modelled as topological spaces that can accommodate a variety of metrics.

Complex systems may display even more radical changes of behaviour as single trajectories may repeatedly bifurcate at consecutive points into a multitude of possible trajectories. Such bifurcating trajectories are characteristic of chaotic systems. Which branch of the trajectory will be selected after the bifurcation is infinitely sensitive to initial conditions and is therefore unpredictable. Each outgoing trajectory thus selected at a bifurcation point may lead to entirely different domains of the state space and encode radically divergent behaviours. In addition to this, points of bifurcation are not necessarily rare. Bifurcations can take place in sequence along a trajectory which makes the corresponding system's behaviour entirely unpredictable, though it is still deterministic. Bifurcations can take the system into a domain where the very number of parameters governing its behaviour changes. As a result, different domains of the system's state space may be of different dimensionality altogether and the system's dynamics may gain or lose degrees of freedom (the latter is a more simple frequent case generally known as self-organization). In the following sections we shall see how these kinds of behaviour are constitutive to the process of becoming.

6.1.3 Manifolds

Two additional important mathematical ideas that were developed in the course of researching the mathematical properties of geometrical spaces in general (Gauss and Riemann) and state spaces in particular (Poincaré) are reflected in Deleuze's construction of multiplicities (DeLanda 2005, pp. 10–14). The first is the idea of manifolds and the second is the associated vector field of rate of change that can be defined on manifolds. The idea of manifolds was a breakthrough in the way geometrical spaces are mathematically described and manipulated (Hirsch 1997). Before the time of Riemann, curved geometrical objects were only described using functional methods, meaning that each and every point in the curved object was described as a function of a few independent space coordinates. For example, a two-dimensional curved object like the surface of a sphere had to be described within a containing three-dimensional space. Additionally, a single mathematical function had to be found to describe the whole curve. Manifolds changed this manner of treating curved objects conceptually and mathematically. Gauss and then Riemann found a way to treat such curved objects as spaces and describe them *without* resorting to an external coordinate system. In other words, manifolds are described in terms of a coordinate system intrinsic to them with exactly the number of dimensions of the object itself. A sphere is then understood as a curved space of two dimensions without an artificial three-dimensional coordinate system containing it. Another important characteristic of manifolds is the fact that a single curved space can be described by a multitude of overlapping coordinate systems which are independent from each other. A manifold, therefore, can be described in terms of a multitude of locally valid descriptions (coordinate systems) that overlap each other; none of these is capable of describing the whole manifold. This is a departure from (and a profound extension of) the single global function per entity that was possible before Riemann.

6.1.4 Differential Vector Field

Last, and perhaps most important, is the method initially developed by Gauss and extended by Riemann of expressing the properties of curved spaces not in terms of their spatial variables but in terms of local changes (differentials) of these variables, i.e. *in terms of differences*. Following Riemann's methods, the whole description of a manifold is given in terms of assigning to each point in the curved space a vector that specifies the direction and amount of the greatest change at that point. This vector expresses everything which is significant about the point; it is computed locally solely from the specific relations of differences between the point and all other points in its immediate neighbourhood. The whole shape of the manifold is therefore determinable by a field of *intrinsic local differences* (vector field) that expresses the *tendencies* of the shape (curvature) at any of its points.

Remarkably, each vector in the vector field is in fact *a relation between differences.* Consider two variables X and Y: a relation such as Y = f(X) relates a determination of a certain Y to the determination of certain X, where X is determined independently of anything else. Consider alternatively a relation of the kind dy/dx: this relation relates differences in a manner which determines neither X nor Y.[14] Moreover, the differences dx and dy do not have an independent specification or an independent identity. The only determination is of the relation dy/dx. *This relation is symmetrical, determining dx and dy reciprocally while allowing no independent determination of either dx or of dy*. Such differential, reciprocally determining relation can of course be extended to any number of differential elements, each being an intrinsic difference corresponding to a specific dimension of the state space. In this manner of reciprocal determination of differences *no final value and therefore no complete identity are brought forth* (Deleuze 1994, pp. 170–176). Extending the example of the piece of metal from Sect. 5, there is a relation between the piece's degree of brightness X and its temperature T_{emp}. But as we have already seen, the actual state of the individual hides virtual differences in both brightness (dX) and temperature (dT_{emp}). Differences in brightness and temperature reciprocally determine each other even prior to any actualization of a particular brightness or temperature. We can now understand the becoming of the piece of metal at any instant T in terms not only of one virtual difference but of a number of reciprocally

[14] Conventionally the differential dx is derived from X and therefore secondary to it. In Deleuze's analysis of the philosophical meaning of calculus, the differential dx is primary in the ontological sense. The differential dx corresponds to the kind of difference described in the previous section.

determining virtual differences. The relatively simple family of trajectories discussed in Sect. 5 is now replaced, in the more realistic situation, by a multidimensional space of interdependent potential variations. We have now gained a much more faithful depiction of the virtual event that corresponds to every actual, empirically observable, instance of reality.

6.1.5 Multiplicities in System Theoretic Perspective

The combination of the above concepts provides the necessary ground needed to understand the concept of multiplicity from a systems theoretic perspective: *A multiplicity is an abstract topography of change underlying the dynamics of actual phenomena.* This is a deceptively simple definition for a profound revolutionary concept. Multiplicity is not a mere mathematical representation or an idea *about* material reality; neither is it external to material reality in the sense that it is conceived in the mind of a thinking agent. The generic characteristics of state space topographies expose, according to Deleuze, a deep structure of existence (and in this the subject-independent aspect of his position is highlighted though it is indeed a simplification). Generic topological structures express a pure dynamism immanent in all actual phenomena but *independent of any specific actual realization*. It is not entirely clear whether Deleuze was familiar with the developments of dynamic systems theory, especially the work of Poincaré. However, his construction of the virtual as a dynamic immanent dimension of reality clearly resonates with the mathematical and philosophical insights achieved by dynamic systems research.

It is important to note that manifolds and differential vector fields are instrumental to the Deleuzian programme in showing how geometrical representations of dynamic systems reflect ontological elements. Without these conceptual breakthroughs there would be no convincing ground to argue that the structures arising from state space representations of dynamic phenomena reflect an underlying ontological dimension which: (a) is immanent to actual phenomena; (b) is constituted from pure differences and thus encodes a structure with no identity; and (c) does not presume any transcendent concepts and observing subjects prior to itself. These are briefly discussed in the following subsections.

6.1.6 Multiplicities are Immanent in Actual Phenomena

Multiplicities are manifolds in the sense that they are structural elements that need no external reference system and no external determination (description) for their specification. Whatever is specified in a multiplicity is specified only in terms intrinsic to it: the number of its intrinsic variables, i.e. its dimensionality[15] and the reciprocally determining relations among the differential elements associated with these variables.

An additional critical point can be noted in Deleuze's careful construction: There is no stand-alone pure virtuality and multiplicities can never have a disembodied existence of the kind that Platonic ideas have. There is a necessary connection between multiplicities and their actual manifestations (see example in Sects. 5 and 6.1.4). Every multiplicity must have

[15] These intrinsic variables are just differentiated elements of pure change. There is no indication in multiplicity as to what they represent in an actual system. Dimensionality is the number of distinct intrinsic differences whose reciprocally determining relations describe the multiplicity or a virtual event. A multiplicity therefore encompasses multiple (indefinite) paths of individuation. The integer number of dimensions is still a point of weakness in this development of the concept because it presupposes a kind of distinctiveness that is reminiscent of that which exists in fixed identities. This difficulty can be overcome by introducing fractal dimensions but the development of this idea is beyond the scope of this paper.

a variety of actual manifestations. As Deleuze writes: "A multiple ideal connection, a differential relation, must be actualized in diverse spatiotemporal relationships, at the same time as its elements are actually incarnated in a variety of terms and forms." (Deleuze 1994, p. 183). The structural features of multiplicities are only implied by observing actual phenomena. These are the effects of change that are empirically observable but once actualized they are not pure change.

Multiplicities are therefore necessarily immanent in material existence and their structure is intrinsic. No transcendental element is needed for their specification, neither an externally imposed frame of reference nor an external observing agent. By this very fact, the construction of multiplicity satisfies the first point of Deleuze's ontological programme.

6.1.7 Multiplicities are Partial Identities

The word 'multiplicity' informs us that this concept belongs exclusively to the 'many' without the need for any unifying element or principle. Multiplicity is an inherent diversity in itself. There is absolutely no 'one' or 'oneness' in multiplicity. Thinking about multiplicity in terms of abstract manifolds highlights an intrinsic multiple structure: there need be no externally imposed reference system and there need be no single unifying description (coordinate system). Multiplicity can be characterized solely by a multitude of local, independent descriptions each with its own dimensionality and reciprocally determining differences.

Next, we have to attend to the differential relations that shape a multiplicity. Thinking of multiplicity in terms of a differential vector field highlights an expression of pure change in terms of local relations between intrinsic differentials. Multiplicity is a continuum literally woven of reciprocally determined differences. The structure, therefore, is intrinsically incomplete. At any point and in its entirety a multiplicity possesses only a partial identity, determinable, yet not determined. The elements of the multiplicity have neither sensible form nor conceptual signification, nor therefore, any assignable function (ibid., p. 183). Clearly, in spite of being structured, multiplicity has no anchor in a fully determinable identity; it is constituted solely from differences. Multiplicity thus conceived accomplishes the second point of the Deleuzian ontological programme.

6.1.8 Ideas as Multiplicities

One of the most significant and innovative propositions of Deleuze's ontological work is replacing the Platonic concept of pure transcendent ideas with multiplicities. Ideas as multiplicities are those structured patterns of change immanent in actual phenomena. Ideas are only conceivable as implied by the effects of their phenomenal actualization. Remarkably, in recasting ideas as multiplicities, the place of the Cartesian thinker is rendered marginal. Ideas as multiplicities are immanent in actual phenomena and therefore enjoy an observer independent status. Ideas need not be the ideas of someone, of a thinking subject. Every actual phenomenon has an intrinsic and productive ideal element—it thinks itself in itself and actualization is but the incomplete manifest of this unending thought (ibid., p. 254). This point highlights the realist flavour of Deleuze's position.[16] Yet it would be an oversimplification just to claim this without adding that the subject of knowledge is itself a

[16] Protevi (2010, p. 13) remarks: "So the interesting sense of realism for Deleuze is that the world has structure, but that structure is the structure of multiply realizable processes, not the structure of fully individuated things which result from those processes." But realizable processes are not enough to account for reality. The process of becoming that integrates the virtual and the actual is the necessary and sufficient account.

product of individuation that involves a multiplicity. There is no ideal subject (or object) that exists a priori to experience but rather a virtual multiplicity that brings forth an actualization of both individuated subject and the individuated object being experienced in the course of becoming. The very distinction subject-object taking place in the event of experience is also determined by this very becoming being already bound by prior histories of individuation.

Accounting for ideas as multiplicities, for how multiplicities are synthesized from virtual differences and for how they bring forth actual phenomena, accomplishes the third point of Deleuze's ontological programme.

As differences constitute multiplicities, multiplicities are the structural elements that constitute the virtual plane. Deleuze relates to multiplicities as 'concrete universals' (ibid., p. 176) and regards them as the building blocks of reality. To develop the structural aspects of multiplicities further we need to address two additional concepts: singularity and assemblage.

6.2 Singularities

Multiplicities are structural elements. As already explained, structure is given locally by the reciprocally determining relations of differences. A multiplicity is first and foremost characterized by the number of its dimensions that corresponds to the number of state parameters in the actual phenomenon it corresponds to, and by the reciprocally determining relations of the differential elements that correspond to each of the dimensions (e.g. expressed as partial differential equations). These give rise to the characteristic global structure of the multiplicity. It is important to note that the given dimensionality and the differential relations that define a multiplicity are *solely* implicated from actual phenomena. Virtual structure is indeed immanent in the actual. Both the actual and virtual are inseparable from and irreducible to each other.

Going back to the metaphor of state space topography, we see that the topographical structure of the state space expressing the system's dynamics is described by the distribution of mathematical singularities within the state space.[17] These singular points and curves, also called attractors, are locations of convergence that *express the general tendencies* apparent in the vector field mentioned above (Figs. 1, 2). There is an important conceptual difference between trajectories being continuous successions of actual states on the one hand and the tendencies expressed by the differential vector field made apparent by the distribution of singularities on the other. Contrary to trajectories, the vector field embodies information about *unrealized* tendencies of the system. These tendencies have no actuality, not even potential actuality, whatsoever (DeLanda 2005, p. 31). They only express manners of pure change and possess therefore only partial identity.[18] The distribution of singularities describes a distinct and rigorous topography of change while being entirely obscure[19] in the sense that the virtual is always hidden underneath the actual but it is that by which the actual becomes what it is!

[17] This proposition is extended later.

[18] The fact that trajectories are computed by performing mathematical integration over the vector field can be deceiving. There is a deep philosophical significance to this integration. It is part of the individuating process that must be carried out to actualize anything.

[19] For Deleuze multiplicities are distinct but obscure. While becoming actual phenomena they undergo a philosophical phase transition and become clear (observable, not hidden, given to representation) yet confused because what is apparent in actuality is clear but never expresses to the fullest the hidden pattern that connects each manifest to the whole of the virtual plane (Deleuze 1994, pp. 213–214; DeLanda 2005, p. 16).

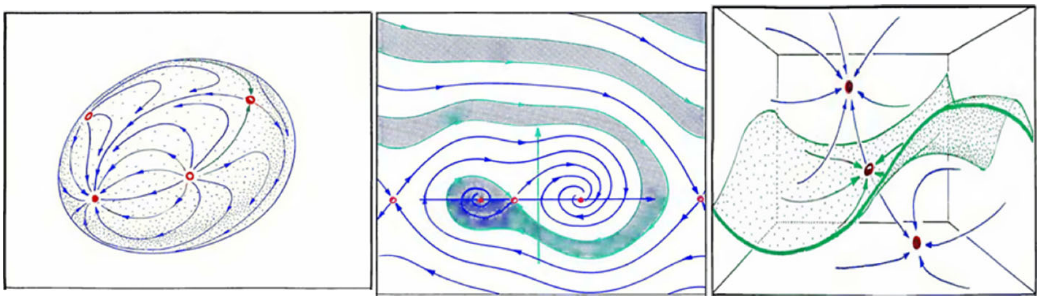

Fig. 1 Distribution of point singularities over a 2 dimensional surface (*left* and *middle*) and a 3 dimensional surface (*right*). *Image credits* Abraham and Shaw (1992)

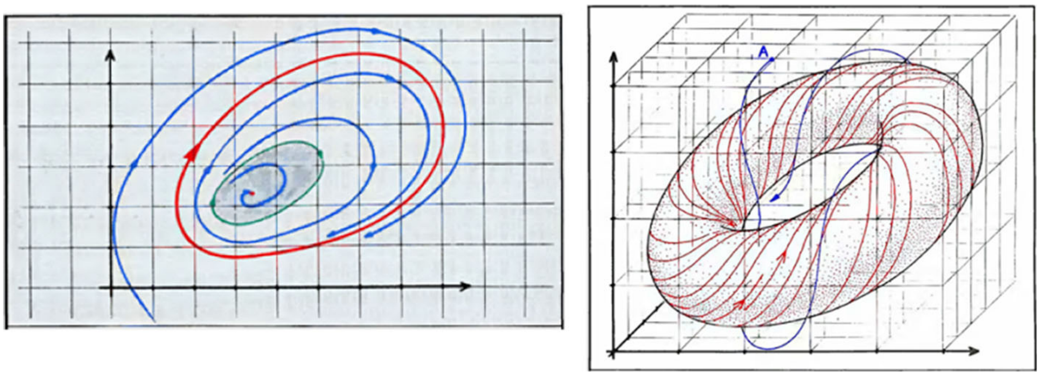

Fig. 2 *Left* curve singularities (limit cycles) in *red* (attractor) and *green* (repulsor); *right* a torus shaped surface singularity (trajectories converge into torus). *Image credits* Abraham and Shaw (1992). (Color figure online)

Deleuze's treatment of singularities goes much further than the simplified mathematical interpretation of singularities[20] given here. For him singularities and their distribution are pragmatic tools constructed to understand a deeper aspect of reality. He divides the structure of multiplicities into regions of ordinary points and significant points. Significant points are all singularities. These are the points that impart structure on their state space neighbourhood. These are attractors, bifurcation points, saddles, ridges separating basins of convergence or divergence etc. What is *interesting*[21] about the multiplicity are the singularities; their distribution fully characterizes it. Ordinary points are points of monotonous change that fill the gaps between singular points. In a manner of speaking, ordinary points are governed by the singularities in their vicinity. Nothing is interesting about ordinary points apart from the fact that they may eventually appear on an actual trajectory. The distribution of singularities, therefore, is the primary object of observation when it comes to the empiricism of the virtual dimension. In Deleuze's terminology, each singularity is an event. Not a temporal event, but an ideal a-temporal event—a turn of destiny in the process of becoming. For example, the point of zero degrees Celsius for water is an event. Whether water turns from solid to liquid or from liquid to solid, something significant is always happening at the point of zero degrees. Each of the sides of the zero point can be both a future and a past in different actualizations.

20 Even when systems do have a mathematical model, it is impossible, in most cases, to compute the distribution of singularities. Such computation is achievable only in extremely simplified cases. But having even a qualitative and partial knowledge of such distribution may already contribute much to the understanding of a system.

21 Interest is intrinsic to multiplicities in the form of singularities. A singularity need not be interesting for something. Interest in this sense is immanent.

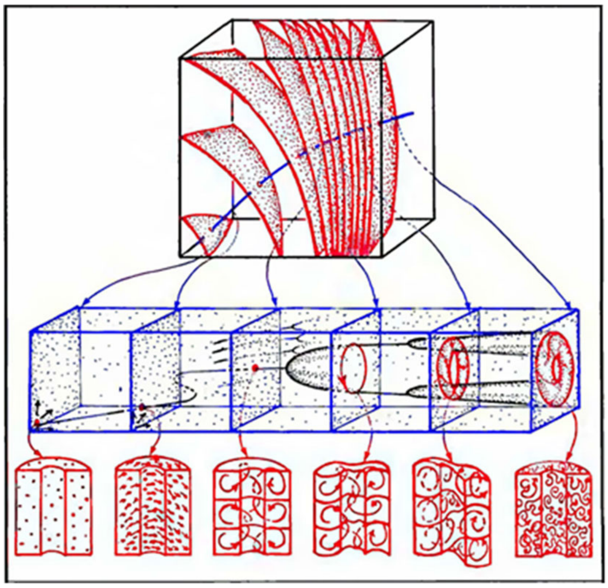

Fig. 3 A sequence of bifurcations in the formation of a turbulent fluid. Each *point* on the *blue curve* above corresponds to a space of vector fields (the *rectangular* in the *middle*). Every *point* in the *rectangular* represents a vector field of the system. All vector fields on the same plane share the same global properties depicted on the diagram below. Each bifurcation opens multiple nested vector fields. A multiplicity with bifurcation points is necessarily structurally unstable. *Image credits* Abraham and Shaw (1992)

6.2.1 Structural Stability and Instability

The virtual space shaped by the distribution of singularities is not a metric space but rather a topological space. Changes in the relative locations of singularities do not qualitatively affect the dynamic patterns of any actual phenomenon as long as the multiplicity undergoes only topologically equivalent transformations. Clearly, topologically equivalent multiplicities produce topologically equivalent trajectories and such trajectories correspond in turn to actual patterns that can differ only quantitatively but not qualitatively. Therefore, a multiplicity is considered structurally stable under all parametric perturbations of the system that may alter it into topologically equivalent variations of itself (ibid., p. 32). This fluid structural character is also coherent with the understanding of difference as a non-metric or rather a proto-metric element.

Structural instability of a multiplicity involves parametric perturbations that may alter its structure into topologically non-equivalent variants. An example of such structural variation is the case of bifurcations. A bifurcation can be understood as a deformation of one vector field into another topologically non-equivalent one (ibid., p. 32). A bifurcation unfolds embedded levels of the multiplicity (Fig. 3). This is why in a multiplicity not all the levels are necessarily given at once. Certain domains of a multiplicity may become accessible only when a process of becoming has already selected certain trajectories that lead into a bifurcation that unfolds in turn into further embedded levels. Indefinitely many bifurcations may take place in a sequence along a trajectory, having a profound complicating effect on the structure of multiplicity. Different levels of such a multiplicity cannot belong to the same moment in time because they necessarily unfold in a sequence of events. It can be said that in such a case the process of becoming brings about time itself (ibid., p. 107).

Insofar as the geometrical metaphor to the structure of multiplicity goes, DeLanda's definition is the clearest: "A multiplicity is a nested set of vector fields related to each other by symmetry breaking bifurcations, together with the distributions of attractors (*singularities*) which define each of its embedded levels." (ibid., p. 32)

It is interesting to compare this quote to one of Deleuze's descriptions that restores the metaphysical sense that has been somewhat lost in the simplified systemic description developed here:

> What is an ideal event? It is a singularity—or rather a set of singularities or of singular points characterizing a mathematical curve, a physical state of affairs, a psychological and moral person. Singularities are turning points and points of in?ection; bottlenecks, knots, foyers, and centres; points of fusion, condensation and boiling; points of tears and joy, sickness and health, hope and anxiety, 'sensitive points'. … [Yet, a singularity] is essentially pre-individual, non-personal, and a-conceptual. It is quite indifferent to the individual and the collective, the personal and the impersonal, the particular and the general—and to their oppositions. Singularity is neutral. (Deleuze 1990, p. 52)

6.3 Assemblages

To complete the picture of the virtual dimension, we still need to account for how multiplicities mesh together to create a virtual continuum, which has already been termed the plane of immanence. By now it is clear that the plane is not a plane in the simple geometrical sense. It is rather a vast interconnected mesh of all multiplicities with varying number of dimensions that span an inexhaustible variety of structural configurations with no unifying principle. The plane is the ultimate manifold—the underlying virtual dimension of the whole of existence.

The way multiplicities mesh is by forming assemblages. The concept of assemblage comes to describe the inherent capacity of multiplicities to affect and be affected by each other. The abstract mechanism at the basis of assemblages is the relating of two series of differences[22] on the virtual plane through a third series which is a series of differences of differences, or, second order difference.[23] An assemblage between multiplicities is formed quite simply when a series of differences belonging to one multiplicity is connected with a series of differences belonging to another multiplicity via a third series of second order differences that expresses certain non-random correspondence properties (Deleuze 1994, pp. 117–118). When this relation of correspondence or resonance is present, the two multiplicities are said to communicate. Put otherwise, when two or more distinct individuals are affecting each other's individuation, they are said to form an assemblage.

It is important to note that while mathematically any two series can be related by a third difference series, not any such relation is communication. There is no way to predict what joint tendencies (and their corresponding actualizations) might arise when two or more multiplicities form an assemblage via a number of series of differences. These joint tendencies emerge as multiplicities affect each other through corresponding or mutually entrained differences. In their potential, not yet actualized virtual state, these joint tendencies are called capacities (and in some places affordances). Capacities as such complement the distribution of singularities in characterizing the structure of multiplicities.[24]

In the actual dimension, an individual (an individuated phenomenon) may be characterized by a fixed number of properties and yet possess an indefinite number of *capacities to affect and be affected* through interactions with other individuals. The degree of openness of this set of potential interactions will vary from individual to individual (DeLanda 2005, p. 62). If every individual is an actualization of a virtual multiplicity, the variety of capacities available

[22] A series of differences is a collection of consecutive differences (a trajectory) that embodies a partial identity. A variable of a multiplicity or a mathematical combination of such variables can be expressed as a series of differences that reflect (or are implied by) a certain type of behaviour in the dynamics of actual systems associated with the said multiplicity.

[23] Higher order differences represent the inherent 'depth' of the virtual dimension because they embody even less identity compared to the lower order differences to which they relate.

[24] An interesting approach to assemblages can be found in Kauffman (1990). Kauffman's strings and random grammars can be understood in terms of differences and multiplicities.

to an individual corresponds to the number of assemblages its originating multiplicity is capable of forming with other multiplicities. This number of potential assemblages is of course indefinite.

Capacities and assemblages are important for a number of reasons: theoretically they describe the manner by which the virtual continuum is being formed from distinct multiplicities. In the actual dimension assemblages give rise to emergent capacities and interactions that are a major source of unpredictable novelty. We can never have a complete knowledge of the capacities of any individuated phenomenon. The best example of a complex assemblage is ecology. An animal may form different assemblages with the ground (digging a hole), with bushes and trees (climbing or hiding), even with ponds (diving underwater) in order to avoid a predator. Each of these activities is a capacity with a corresponding assemblage of multiplicities. Ecology in general possesses an immense potential of novelty through the formation of such assemblages. Other, more concrete examples would be the phenomenon of symbiosis, the co-evolution of species and coordination of actions within social assemblages of organisms (Maturana and Varela 1998). In all probability, it is assemblages (as not accurately fitting systems) that were the enabling factor for the greatest explosion of novelty in life—the emergence of multi-cellular life forms from single cells about 800,000 million years ago. Recently, against the accepted dogma that rigid structural formation of proteins through folding is necessary to proper function, it was discovered that many proteins, especially those which are involved in multiple cellular functions, have significant parts that are not rigidly folded. These proteins actually form a variety of flexible assemblages (Chouard 2011). There is no doubt that assemblages are involved in the vast novelty life produces at all scales, from the intra-cellular level to the whole biosphere.

In every such example novel capacities to affect and be affected emerge in the actual individuals participating in the assemblage. In a later work with Felix Guttari (Deleuze and Guttari 2005, pp. 3–25), Deleuze introduces the powerful concept of Rhizome, which is a heterogeneous assemblage. Rhizomatic systems are structures that significantly depart from the orthodox scheme of stable and well-defined input/output relations. Connections are not pre-given but are produced as part of the system's dynamics.

Assemblages are serendipitous, opportunistic and inexact.[25] They stand in sharp contrast to the Newtonian mechanistic view of ultimately deterministic and rigorous connections between physical elements interacting through universal laws. The formation of assemblages does not come to argue a case against physical laws. Assemblages, on the contrary, show the immense novelty allowed by the laws of physics and the unpredictability of the phenomena they bring forth in real world situations, i.e. outside the narrow class of simplified highly controlled experiments carried out in laboratories.

In conclusion, it is worth reflecting on the conditions that allow speaking of multiplicity as having a concrete structure. The virtual, being a landscape of pure difference, is of inexhaustible expression but nothing in it *presupposes* structure. Remarkably, however, not everything goes either. How come and under what conditions, if so, can we speak of the virtual as having any structure at all?

As has already been explained, the structure of multiplicity, inasmuch as structure can be brought forth and spoken of,[26] is always implied by actual empirical phenomena. There are no multiplicities which can be otherwise structured. The specification of multiplicities

[25] The major source of the flexibility of assemblages is that the nature of connections among virtual differential elements is topological and not metric.

[26] Beyond multiplicities there are assemblages that retain a partial structure which is pre-individual, and beyond them there is a continuum of difference with ever diminishing structural content—an open-ended 'wilderness' of pure potentiality. See also footnote 34.

as structured elements (i.e. their dimensionality, the reciprocally determining differential relations and their corresponding distributions of singularities) always derives from diverse empirical observations of the actual. This necessary derivation establishes one direction (actual –> virtual) in the profound reciprocally determining relations between the virtual and the actual dimensions of existence in Deleuze's ontology (Williams 2003, pp. 7–13). Next, we develop the concept of becoming as the complementary direction of this reciprocity, i.e. the manner by which virtual patterns guide the individuation of actual phenomena (virtual –> actual).

7 Becoming

Difference, multiplicity and the virtual plane of immanence answer the 'What?' of existence, namely, what are the ontological elements of existence. The following sections are dedicated to answering the 'How?' or, how actual existence arises as the expression of virtual patterns. Virtual patterns are a continuum of determinable yet undetermined non-individual partial identities. The actual—the phenomenal aspect of existence, in contrast, is populated by clear individual identities and the distinct characteristics and qualities that define them. The process of becoming is the process by which the former are incarnated in the latter. The actual is an effect—a product of becoming. Inasmuch as the actual is sensible (given to the senses i.e. empirical) it tends to hide and cover the history of its becoming. It is like a landscape that hides the historical geological processes that shaped it. Whatever can be known about the process of becoming, therefore, is only implicit in actual forms.

In contrast to former metaphysical approaches that are based on ideal essences or categorical species as the basis of identity, Deleuze's philosophy of becoming is a philosophy of individuals. It defines the individual as a structure of relations holding between the virtual and the actual (ibid., p. 204). This is perhaps the most significant feature of Deleuze's ontology: the individual, be it a phenomenon, a quality, a concept, a person or a species is inseparable from individuation—the process of its becoming and from its pre-individual dimension—the virtual field of immanent differences. In all these Deleuze is importantly influenced by Simondon's philosophy of individuation (Simondon and Garelli 1995; Deleuze 2004, pp. 86–89; Del Lucchese 2009). Existence, therefore, is becoming—an on-going creative expression of difference. The profound significance of becoming is grasped only through fully embracing the individual, its ultimate uniqueness and inherent incompleteness. Identity and resemblance do of course exist but only as superficial secondary effects while their intrinsic differences are either disregarded, or equalized and distributed in the actual properties and qualities that disguise them (the shape of the mountain ridge disguises the intensive mechanical tensions that brought it forth).

No actual phenomenon is ever entirely determined and thus separated from the virtual. There is always more to the actual than what is observable: a hidden immanent potentiality. Even what may seem to be complete determined identities harbour underneath indeterminate multiplicity.[27] At any instance, certain determined aspects of a phenomenon can be undone due to perturbations of other, less apparent, aspects. Actual structures can lose their coherence while the underlying multiplicity gives rise to novel actualities. This is, as we will see, an evolutionary selective process.

The philosophy of becoming is a complex theme in Deleuze's work and the presentation given here is only a simplified introduction. Yet the profound significance of this ontology

[27] A compelling example is physical vacuum that undergoes quantum fluctuations.

to the science of complex systems can be captured by the following four complementary ideas/approaches, each characterizing an aspect of becoming:

1. Intensive differences.
2. Progressive determination (repetition, self-organization).
3. Quasi-causation.
4. Becoming and virtual connectionism.

7.1 Intensive Differences[28] (Intensities)

The initial understanding of intensity and intensive differences[29] was already given in the overview Sect. 3. Intensive differences are, according to Deleuze, the sufficient reason of all phenomena. He writes: "The reason of the sensible, the condition of that which appears, is not space and time but the Unequal in itself, disparateness as it is determined and comprised in difference of intensity, in intensity as difference." (1994, pp. 222–223). The term 'sensible' here relates to anything that can be sensed; not sensed only as in producing an impression for an observer, but in a much wider meaning of producing an effect upon something else. In other words: producing a difference not in itself but for something other than itself. My interpretation of the sensible here is reminiscent of Bateson's definition of information as a "difference that makes a difference". Deleuze's philosophy of becoming attributes a whole new dimension to this understanding of information.

In simple terms intensive differences are affective expressions of corresponding virtual pure differences. A series of pure differences may be expressed as a temperature gradient in one system, an electromagnetic gradient in another system, a difference in distribution of organisms over an ecological niche etc. These are examples of a variety of intensive differences. If various systems embed a single pattern of pure differences, the dynamic pattern guiding their becoming will be similar. However, since each system expresses a unique intensity, the actual individuated phenomenon manifested will turn out to be entirely unique: the temperature intensity will, for example, drive and redistribute energy and matter of a fluid; the electromagnetic intensity will mobilize electric charges; and the unequal concentration of organisms will produce a migration. Different phenomena arise governed by the same virtual pattern ('same' here is only a figure of speech as virtual patterns are different in themselves).

In the process of becoming, qualities and characteristics of actual phenomena are individuated and become distinct by the cancellation of intensive differences and the elimination of the unequal in its distribution. Moreover, phenomenal change takes place only as an effect of cancellation of difference (Deleuze 1994, p. 223). This abstract notion of becoming is clarified if we note that the tendency towards cancellation of difference simply reflects the presence of singularities in the virtual multiplicity. According to system dynamics, singularities are points or limits on trajectories where some or all of the intrinsic components of the differential vector field become nullified, which literally means that differences are cancelled. Under the assumption of continuity, differential vectors tend to diminish in size as trajectories approach the vicinity of singularities.

Inasmuch as each trajectory is the convergence of a virtual multiplicity into a unique actual manifestation, the distinct characteristics of such manifestations correspond to virtual singularities. The arising of distinctiveness and individuality in actual phenomena corresponds,

[28] Intensive differences must not be confused with external phenomenal differences, which distinguish between actual (formed) individuals and are based on representational identities.

[29] Intensive differences must not be confused with external phenomenal differences, which distinguish between actual (formed) individuals and are based on representational identities.

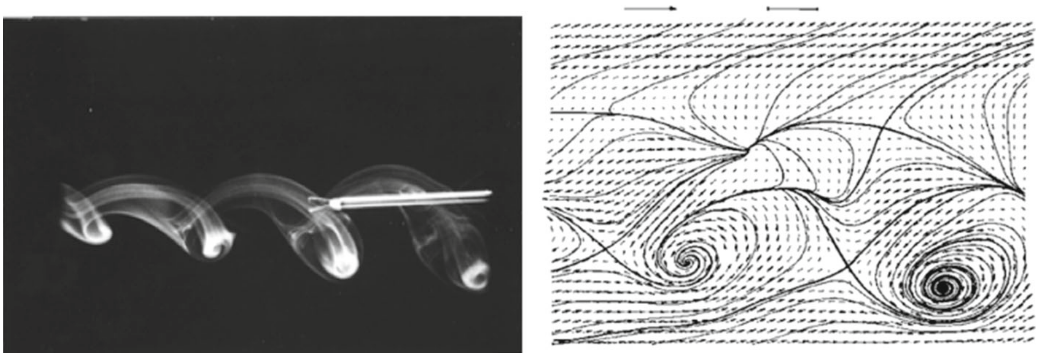

Fig. 4 A smoke wake (*left*) illustrates an intensive process and the corresponding implied multiplicity immanent in it (*right*). Images from http://www.mech.unimelb.edu.au/fluids/, *Credits* Perry and Lim (1978), Perry and Tan (1984)

therefore, to the cancellation of differences in the neighbourhood of virtual singularities. This is why the distribution of singularities is indeed the significant aspect of a multiplicity, as explained earlier (see Fig. 4 for visual example).

Deleuze is careful to affirm that there is no cancellation or equalization of differences in the virtual, only in becoming (ibid., p. 228). The tendency of intensive differences to cancel in the process of becoming is only an external effect. This asymptotic tendency of equalization is the mechanism by which differences bring forth identities as a secondary effect. An identity is nothing but an effect concomitant to cases where intrinsic differences are not relevant or not effective. In other words, we grasp identities not by recognizing in them an essential or categorical element but by selectively disregarding differences that make them unique, incomparable and unqualified instances.[30] The only effect that becoming has on the virtual plane is that of hiding the rich heterogeneous structure of multiplicities underneath its individuated products.

In the case of non-equilibrium open systems, intensities are never cancelled or even get close to a state of cancellation. Such systems manifest *actual productive processes* where the process of becoming is observable (externalized). Such observable productive processes are characterized by *partially individuated* phenomena that can hardly be categorized or modelled in terms of even approximate representational identities (e.g. turbulence in far from equilibrium systems).

7.2 Progressive Determination

Becoming is a morphogenetic process. Virtual elements become progressively determined and by that are being actualized as measurable extensive properties and qualities of distinct phenomena. In terms of the systemic understanding of multiplicities, becoming is a progressive determination of a trajectory within state space. In simplified terms it is represented by the mathematical integration of the multiplicity's vector field resulting in actual trajectories. Philosophically, it means that becoming can be understood as a spontaneous computational process that produces information. For the majority of cases, however, besides the extremely simple systems, the computational process involved is intractable and does not yield to reductive algorithmic or procedural representations. The process is too complex and can be

[30] To characterize something as black we must disregard an indefinite number of shades and nuances and the indefinite relations these may hold in perception to shades and nuances of other colours etc.

described mainly in qualitative terms using models based on simplifying assumptions that disregard much of the inherent indeterminacy that is involved.

Scientific knowledge is based on a method of observation in which a system is put in a carefully designed experimental setup made to create more or less sterile circumstances for the system. In such circumstances, if successful, the virtual dimension of the studied phenomenon is almost entirely neutralized, that is, it is forced to produce a narrow variety of trajectories in the studied system's state space. From such trajectories, inferences regarding the general dynamics of the system are made, but such inferences are useful mostly for very simple cases. This is the only way experiments can be faithfully reproduced, and reproducibility is a necessary requirement for credible scientific results. This method, however, seriously limits the domain of possible scientific knowledge. It can be said the systems under scientific examination are to a large extent 'dead' systems whose dynamism is confined to the minimum possible. In reality, irrespective of any experimental setup, multiplicities are meshed together into a continuum and their structure is affected by the opportunistic assemblages they form with other multiplicities. They can and do in fact produce a vastly larger span of phenomenal effects than what can be possibly captured by inferences from trajectories that explore only very limited territories of the virtual plane.

Furthermore, the very requirement of reproducibility in scientific experiments is an idealization based on the assumption that reality is constituted from identities and essences. Reproducibility in science comes to support the claim that the results of experiments successfully isolate and expose the essential invariant properties of the examined phenomenon. The scientific method is in fact a method of establishing or 'discovering' identities and invariant properties. The very credence of scientific knowledge and its association with truth is grounded in this approach.

According to the ontology of difference, repetition is always a repetition of a difference. Reproducibility is perhaps empirically possible by imposing strict enough prior determinations and discarding certain differences as irrelevant for the theory at hand but it is nevertheless ontologically impossible. In other words, the discoveries of science involve only a narrow and superficial aspect of reality. For example, we can briefly examine the difference between two-body problems versus n-body ($n > 2$) problems in classical Newtonian gravity. These problems deal with computing the spatial trajectories of massive bodies that interact through gravity. The number associated with the problem is the number of massive bodies involved in the setup. Two-body problems are solvable analytically while n-body problems are too complex for analytical methods. In fact there are no two-body problems in reality. A two-body problem is just an idealization where the process of becoming of the physical system is such that it can be made fully determined, while in actual problems, even though the system is determinable (since we know the dynamic equations of gravity), it cannot be determined at once (i.e. computed by using an analytic formula). A generalization of this argument is further developed by Stephen Wolfram in his book *A New Kind of Science* (2002) to include general systems. Wolfram discusses at length the limitations of contemporary science and supports his thesis by pointing to the limits of mathematical analysis and general computability. Wolfram's theses use a conceptual framework based on cellular automata but in fact they reflect the deeper (and mostly intractable) problem of determination in the process of becoming.

It is important to note that becoming is inherently complex and intractable because it is a progressive determination. This means that determination of trajectories does not take place all at once but in a succession of determining events. Every such event is selective in the sense that subsequent paths and events are indeterminate before the event takes place (see DeLanda's definition of multiplicity in Sect.6.2.1).

The first level of determination in the process of becoming is the individuating field. At this level, virtual differences are incarnated as intensive differences; that is, a pattern of difference expresses a sensible effect. The sense—the difference that is made (following Bateson) implies (the structure of) the virtual dimension immanent in it and sets the individuating context: for example, a meteorological pressure system, imbalance of prices in a stock market, new specie within an ecological niche etc. A multiplicity will produce entirely different kinds of phenomena in different intensive setups that incarnate it.

The individuating context also includes the determination of the assemblages involved. These assemblages bring forth capacities of affection and interaction which are not determined by the structure of a single multiplicity. For example, the assemblage a human anatomy creates with the ground selects capacities such as walking, running, crawling or just sitting or lying. These are entirely different from capacities such as swimming or diving selected by the assemblage a human anatomy creates with water.[31] The intensive setup plus the assemblages involved together determine the field of individuating activities within which further determinations of a multiplicity are to take place.

Subsequent determining events driven by intensive differences take place within the individuating field. As already mentioned, not everything is determined at once and therefore becoming, though it is a process that follows necessary lawful determinations at any given instance, is inherently indeterministic (e.g. involving multiple developments from the same initial situation such as in the case of chaotic bifurcation). The outcome of becoming can never be predicted in the general case.[32] That is why becoming is both productive and creative: every actual trajectory is a novel expression of a virtual multiplicity.

The trajectory-forming determining events are of two major categories. The first category includes transition and bifurcation events. Transitions and bifurcations are usually associated with the presence of critical differences; they are best understood in terms of the underlying structure of multiplicities. It has already been mentioned that multiplicities are topological structures rather than metric. This means that distributions of singularities that are symmetric under topological transformations, such as bending, stretching and deforming, are considered equivalent and therefore constitute a single multiplicity. A transition event is an event where the structure defined by the distribution of singularities undergoes a phase transition into another, topologically *non-equivalent* distribution of singularities. A bifurcation event is where nested multiple layers of the multiplicity's vector field are exposed and the system 'selects'[33] which branch of the bifurcation it will follow. Every such branch is characterized by a unique distribution of singularities and the selection determines which sets of trajectories become further accessible to the subsequent process and which are eliminated from the current instance of actuation. Bifurcations are cases of symmetry breaking in regard to the structure of the multiplicity and the patterns of becoming immanent in it (DeLanda 2005, pp. 18–20). The branches coming out of a bifurcation are distinct from each other and the selection of a single branch makes the whole system less symmetric than it was before. In a cascade of bifurcations, each selection makes the system more specific as the shape of trajectories is progressively determined.

Remarkably, transitions and bifurcation events are symmetrical in the sense that a process can progress through such points in both directions. Specifically, in bifurcation, the system

[31] These assemblages imply of course the meshing of multiplicities at the virtual dimension.

[32] Additionally, certain events can introduce new intensities and involve new assemblages, and hence dynamically modify the individuating field (a man runs into the water and starts swimming).

[33] 'Select' is only partially appropriate here because there is no selective criterion involved. This is rather an intractable chance event.

can progress from the branched side to the unified side, which means from a more determined state to a less determined and more symmetric state. Such transitions have a special place in Deleuze's philosophy and are called 'lines of flight' (ibid., p. 225). These are trajectories by which a system escapes a highly individuated state into a less identified and more fluid state (i.e. away from an actual manifest and closer to the virtual plane). Such escape processes, which designate disintegration of order and identity, are part of the process of becoming as well and are called in some places counter-actualization processes.

The second category of determining events is the development of an actual trajectory within a specific layer of the multiplicity. Such processes lead either to subsequent bifurcations or into one of the basins of convergence that are shaped by the distribution of singularities. Settling into a basin of convergence is associated, as already mentioned, with reduction in the degrees of freedom of the system (self-organization) and with the cancellation of (at least some of) the intensities that drive the process. The actual product in such cases is a characteristic asymptotic stable state of the system, or alternatively, any conceivable pattern of repeating periodic or quasi-periodic behaviour.

In cases of non-equilibrium systems, there is no such convergence and there is no cancellation of intensities. Such systems usually go through an indefinite series of bifurcation events that usually manifest as chaotic phenomena. Chaotic phenomena express an inherent structural instability of the virtual multiplicity immanent in it. In other, even less structured cases, the trajectories are not chaotic but are driven in and out of the given basins of convergence and settle neither on a steady state nor on a periodic behaviour, displaying irregular complex trajectories.

The progressive determination of trajectories guided by multiplicities and driven by intensities is what becoming is all about. Besides a small class of systems in strict and temporary circumstances the trajectories are developing indefinitely and always include an unpredictable aspect which is none other than the yet unexplored territories of the virtual multiplicity. Since assemblages, being part of a greater individuating field and a greater expanse of the virtual plane, are themselves dynamic, a change in active assemblages may always perturb the system enough to leave its current trajectory and embark on another, or alternatively reach a transition point, bifurcate etc.

7.3 Quasi-Causation

The process of becoming cannot be understood in terms of chains of causes and effects like those characterizing actual processes. The dynamic relations holding between the virtual and the actual that bring forth the individual are intensive and expressive but never causative per se. Virtual patterns *guide the becoming* of actual phenomena; *they do not cause* actual phenomena. There are a few reasons for this profound observation that invite a further investigation of the unique nature of becoming.

The first reason is that cause-effect relations are based on identities. In order to establish a cause-effect relation, both the cause and the effect must have clear and distinct identities. On the virtual plane and in the process of becoming, partial identities are involved that are not clear and distinct. These are elements in the course of determination, which in principle never completes. Clearly, such elements do not fall under what we may normally consider as proper causes or effects. It can be said that insofar as partial identities are considered, causes and effects are meshed in such a manner that they cannot be distinguished. This state of affairs is well known in complex systems with high interconnectivity and interactivity among components such as organic neural networks. The dynamics of such systems often present distinct behaviours that cannot be reduced or associated with distinct chains of causes and effects. According to the philosophy of becoming, this irreducibility is not merely empirical but rather ontological. Partial identities are real elements, and the becoming of actual phenomena is therefore real but not causal in the strict sense. When it comes to becoming, an alternative to causal explanations is needed.

From a different perspective, while the actual is populated by distinct elements that may hold proper causative relations among them, the virtual plane is populated by multiplicities that are causally sterile; they cannot cause anything to happen and nothing in them is an effect. The reason multiplicities are causatively sterile is because they are pure forms independent of any particular mechanism. In other words, differences and relations between differences cannot produce effects in the temporal sense. Each multiplicity can be actualized by an indefinite number of diverse systems of intensive elements which cannot possibly share any causative resemblance to each other. Yet, in each particular case it is the virtual pattern that governs the becoming of actual effects and forms. The virtual is always precedent to the actual. This is not a temporal or causative precedence but rather the precedence of difference to identity and of the undetermined to the determined. The problem that becomes apparent here is how distinct actual effects develop from virtual causally sterile differences. If the virtual lacks any affective powers whatsoever, there is a doubt whether it is anything more than a mere abstraction.

A third and even more subtle and difficult aspect of the same problem is to explain how virtual multiplicities affect each other. As was already mentioned in Sect. 6.3 multiplicities communicate through two or more series of differences that correlate or resonate via a third series of differences of differences. Intuitively, such mediating series must embody a certain correlating or invariance relation between the two series. Such invariance would imply, however, an identity that underlies the interaction. In relation to this Deleuze writes:

> The most important difficulty, however, remains: is it really difference which relates different to different in these intensive systems? Does the difference between differences relate difference to itself without any other intermediary? When we speak of communication between heterogeneous systems, of coupling and resonance, does this not imply a minimum of resemblance between the series, and an identity in the agent which brings about the communication? Would not 'too much' difference between the series render any such operation impossible? (Deleuze 1994, pp. 119–120)

Deleuze is careful not to reintroduce identity through the back door into his ontological construction of the virtual and by that jeopardize his whole project. His attempt culminates in developing a new concept that will resolve this difficulty. This is the concept of quasi-causation.

It is beyond the scope of this work to follow in detail the intricate development of the concept (see for example: Deleuze 1994, pp. 117–120), but a few highlights are in order, again for their significance to systemic thinking. Quasi-causation must embody a mechanism of affection without the presumption of identity either of the affecting or of the affected elements, or indeed, most importantly, of the relation between them. Interestingly, Deleuze does not propose a philosophical principle that will replace causation in the case of incomplete identities. On the contrary, he offers a variety of mechanisms: "As we shall see, given the variety among systems, this role [of quasi-causation] is fulfilled by quite diverse determinations. The question is to know in any given case how the precursor [the quasi-causative operator] fulfils this role". In simple terms, influences from one series of differences on another are themselves products of individuation. Causation as we come to know it in actuality is therefore an individuated product of becoming; it is not a manifest of a pre-given principle. Remarkably, this would mean that even actual cause-effect relations could not be considered invariant. They are subject to variations since they too have a virtual aspect.

A quasi-causal operator, no matter its particular system-dependent implementation, facilitates a transfer of information from one series of differences to another via a second order series of differences. Following the definition of intensity given above, every (second order) mediating series can be considered as an intensive difference that (in this case) mobilizes information. The quasi-causal operator is an intensity that mobilizes information. As such, it can be understood as a (symmetrical) communication channel (DeLanda 2005, pp. 76–77; Deleuze 1994, p. 120). In the mathematical sense, which is of help here, a communication channel has nothing to do with the signs being communicated, yet it sets reciprocally determined probabilities between the communicating variables (in this case series of differences). This is a description that implies, of course, an underlying multiplicity.[34]

An interesting concrete example would be the game of backgammon, which is a game combining luck and skill. Given a specific throw of dice at the beginning the problem is whether there is a move, out of a few possible, that can be considered the best. For some throws the best moves are pretty obvious but for other throws there are a few options and the best one is not obvious at all. The way to address the problem systematically is to play a sufficiently large number of random games (games with random moves except the first move) to find out if some opening moves are more probable to land victory for the player that made them than others. This kind of analysis (called Monte Carlo analysis) yields that indeed certain opening moves are better than others, a result which is not intuitive, as a large number of dice throws governs the development of each game from start to end. If we examine possible relations between a series of opening moves played by a player and the number of that player's wins over a large enough number of games against players with evenly distributed proficiency, we will find a weak yet significant correlation. But this kind of correlation cannot rise to the status of a direct cause because no single outcome is determinable.

From a Deleuzian perspective, the whole game is guided by a multiplicity. The opening moves (per distinct dice throws) are the first determinations and the whole game can be thought of as a process of becoming. Each single game can be thought of as a single actual event, and a series of games represents a series of discrete actualizations of the underlying multiplicity. What is significant for our subject matter is that the virtual multiplicity somehow correlates opening moves determinations to final state determinations, given a large enough number of games. It is clear that this multiplicity does not possess causative effects. Its differences only involve the developments from each board state to others and every such development is conditioned by a random dice throw and the number of legal moves possible per that dice outcome. Yet, the apparent influence of starting moves on the outcome of games is empirically testable. What is the hidden virtual factor that is exposed here only after a large number of games have been played? We would argue that this is a demonstration of a quasi-causal element intrinsic to the backgammon multiplicity. The intensities involved are clearly connected to dice throws and how they are being 'channelled' (distributed) towards the game's goal via the more or less skilful moves of the players. Clearly, a large number of games averages out all intermediate effects and leaves only the fragmented effect of the opening moves to be somehow accumulated. But this distinct effect can hardly propagate along a single path of individuation of the game. It belongs, so to say, only to the myriad paths taken along many individual and causally independent games, or in other words, to

[34] The communication of the series is an effect of a determination of trajectory in the multiplicity that underlies the mediating series.

the guiding multiplicity itself. It possesses, therefore, no identity or invariant property, but rather a fragmented pre-individual existence that belongs to the virtual and only in rare cases undergoes enough individuation to gain an empirically valid status of a causative agent in the unfolding of a single game. This kind of quasi-causal influence seems to be most common in complex systems.

What this example comes down to is that the effect of mobilization of information between series of differences can facilitate quasi-causal relations at all levels of becoming and such facilitation is consistent with the primary ontological status of virtual differences: identity remains an effect, a product of individuation and not a pre-condition. Additionally, this association of quasi-causation and information channels opens a research avenue towards the possible construction of models and simulation of the process of becoming.

7.4 Becoming and Virtual Connectionism

Dynamic connectionist models occupy an important if not central place in understanding complexity (Ciliers 1998). It is worth exploring in brief how Deleuzian ontology and the process of becoming may be described by way of connectionist concepts.

The virtual plane, being a continuum of pure differences, is a vast multiplicity where everything can be said to be interconnected. This is, however, not the case of distinct elements being distinctively connected as one imagines a network, but rather the case of virtual elements that are never entirely distinct from each other.[35]

It is consistent with a Deleuzian view of existence to describe the state of affairs of existence at any instance as follows: The actual dimension is the sum total of all virtual connections that become explicit at that instance, while the virtual depth underlying the actual is the rest of the connections which, though virtually existing with more or less distinctiveness, are hidden and only implicit.

The dynamism of becoming is such that from instance to instance certain connections that were hidden become (more) explicit, constituting distinct identities (thus sensible), while other connections that were distinct become less so—more implicit, diminishingly distinct and eventually disappearing into indistinctiveness. This dynamic relation between the actual and the virtual is such that while the virtual dimension provides the creative potential (what connections are available and at what level of determination and distinctiveness), the actual dimension of existence is the selective element in the dynamism of becoming (determining what connections may become more or less explicit). Virtual multiplicities guide the determination of trajectories in the course of becoming; the structure of multiplicity specifies the options for relations among differences to become more or less determined (in the vicinity of singularities, for example, they generally become more determined). Yet, as already explained, the structure of virtual multiplicities is implied from actual phenomena. This is how actual phenomena through the mediation of multiplicities are selective in the process of becoming.

The significance of this perspective, besides being conversant with already established approaches to complexity, is that it alludes to a powerful metaphysical evolutionary principle, as we will see in the next section.

[35] The concept of unilateral determination of differences is particularly powerful in that it allows the virtual plane to include *all potential connections* but in various degrees of distinctiveness. The continuum of distinctiveness never falls into the ultimate static condition of 'containing all possibilities': Distinct features (connections) can indefinitely differentiate from an indistinct ground while they can also disappear into a featureless ground. The profound meaning of difference is exactly this: a metaphysically dynamic and indefinitely creative existence.

8 Complexity and the Philosophy of Becoming

How does the Deleuzian philosophical perspective contribute to the study of complexity and complex systems? The kinds of systems we address here are primarily those with one or more of the following characteristics, which are often overlapping:

1. Systems whose structure and/or behaviour do not fit into a single descriptive method or descriptive framework e.g. ecological systems, nation states, sociotechnological systems and human relations in general.
2. Systems with ambiguous contours, ambiguous components and relations among components, ambiguous behaviours, capacities and sensitivities, and other systems that cannot have complete characterization (whether deterministic or not) e.g. cities, large organizations, markets and economies.
3. Productive, innovative, creative systems that produce novel behaviours and structures e.g. social groups, languages and sign systems, brains/minds.
4. Open systems—whose structure and behaviour significantly depend on their interactions and exchange (of matter energy and information) with their environment e.g. organisms, markets, societies and other dissipative systems.

The common denominator of such systems is that they cannot be described or understood as having a consistent and persistent identity. Any attempt to impose identity on such systems eventually fails. Remarkably, in the light of the Deleuzian programme, this is not a mere epistemological failure having to do with the shortcomings of either perception or conceptualization; it is rather an ontological failure.

The primary contribution of the philosophy of becoming to the study of complex systems is an adequate ontology—an evolutionary ontology. Evolutionary in the sense meant here is profoundly different from the common use of the concept in the life sciences and its transdisciplinary extensions afterwards (Campbell 1997; Dawkins 1985). While evolution theory is a theory that comes to account for diversity, Deleuze asserts that diversity is given as the effect of difference.[36] What needs to be explained, therefore, is not how empirical diversity arises from a primordial unity but rather the other way around: how are concrete identities accounted for? Identity having lost its ontological primacy can be spoken of only as a product, an effect whose intrinsic sameness is banished. To replace identity as an ontological element, Deleuze introduces individuals teeming with intrinsic virtual differences and inseparable from an ever-on-going process of individuation. In this sense, Darwin's principle of natural selection and Campbell's selective retention do not account for diversity; *they rather account for its limits*—why certain forms repeat and persist with little variation while other forms do not.

That is why Deleuze finds Nietzsche's idea of eternal return so significant (Deleuze 2006, pp. 23–24; 1994, pp. 40–41, 125, 241). Nietzsche's active powers (intensities shaped by ideas as multiplicities) are brought to the limits of what they can do in actualization. The actual is what returns[37] and what is affirmed in the being of becoming. Actualization is not only a becoming. It is also an *overcoming* because difference underneath what seemingly 'is' will return, both destroying the limit found in the determination that brought along actual existence and bringing forth a novel actual instance of the idea (multiplicity). Here Deleuze also reaffirms Nietzsche's view that there is nothing to existence but the eternal return, but what returns is never the same but the different. Deleuze writes: "Every body,

[36] "The reason of the sensible, the condition of that which appears is not space and time but the Unequal in itself…" See Sect. 7.1.

[37] Deleuze's concept of repetition draws also from Hume's idea on habits see Deleuze (1991).

every thing, thinks and is a thought to the extent that, reduced to its intensive reasons, it expresses an Idea the actualization of which it determines [...] The thinker, undoubtedly the thinker of eternal return, is the individual, the universal individual." (Deleuze 1994, p. 254). And later he adds: "The highest test is to understand the eternal return as a selective thought, and repetition in the eternal return as selective being." (ibid, p. 298). Selection here is neither 'natural' nor 'universal' as both are attributed to empirical processes. Selection here is ontological and implies determinations that bring forth individuals. The actual individual, the product of determinations that brings the Idea to the limits of what it can do is in turn the 'thinker' of the virtual idea it expresses. In 'thinking' it selects; in selecting it returns as difference.

We immediately see that the characteristics of complex systems mentioned above only highlight various difficulties in relation to the presupposition of identity. Once we apply Deleuze's evolutionary ontology these difficulties dissolve. Moreover, we realize that the real research issue with complex systems is not so much their diversity but rather the particular limits of their diversity: how such limits develop (become more or less determined) as well as the nature of the specific determinations entailed in such developments. More determined limits correspond to so-called well-behaving systems while less determined limits correspond to systems with wilder and more unpredictable (though still deterministic) behaviours.[38,39] In other words, the evolution of systems is to do with their processes of determination i.e. their becoming. In his later works with Guttari, the distinction between Deleuze's concept of evolution that coincides with becoming and the conventional concept is quite clear:

> Finally, becoming is not an evolution, at least not an evolution by descent and filiation... It concerns alliance. If evolution includes any veritable becomings, it is in the domain of *symbioses* that bring into play beings of totally different scales and kingdoms, with no possible filiations. There is a block of becoming that snaps up the wasp and the orchid, but from which no wasp-orchid can ever descend. (Deleuze and Guttari 2005, p. 253).

Why are symbioses so significant?[40] Because in each symbiotic relation we find a developing limit on the diversity of determinations, a reciprocal constraint on developing intensities and a meeting of wills (as Nietzsche would have put it) in the interactions of concrete individuals. It is this limit that brings forth a novel actuality that returns. In the more technical terminology of dynamic systems this is called self-organization (Ashby 1962).

It is less clear, however, why Deleuze and Guttari do not consider selective retention of adaptive variations as a significant principle when it comes to novelty producing systems (veritable becomings), all the more so knowing that these principles are the 'explanatory engine' behind the modern evolutionary synthesis and its extensions. The reason may be that gradual adaptations explore the diversity of expressions of a given idea (multiplicity) but only rarely, if at all, amount to the transformation of the virtual idea itself. The selection of adaptive variations works in fact against difference and in the direction of eliminating the intensities in the relations between a species and its ecological niche (in the biological context). Adaptation is therefore a kind of activity that tends to stabilize the idea or, in the

[38] Systems involving quantum effects are a special case. The wave function is still deterministic; only its measurements require probabilistic considerations. This is a topic for further research.

[39] Less determined limits of diversity must not be confused with chaotic behaviours. Chaotic attractors for example may still belong to well-determined limits of diversity.

[40] See Gontier (2007) on the idea of universal symbiogenesis.

Deleuzian terminology, to further territorialize[41] it. The distinction made here is important because it goes beyond standard evolution theory: changes in the limits of diversity that can be considered as new becomings are not those that involve merely empirically modified (phenotypic) expressions but also involve the de-territorialization and the eventual transformation of (virtual) ideas either through the formation of new assemblages[42] (i.e. alliances, symbioses) or otherwise.[43] In the context of biological evolution such transformations can be associated with macro-evolutionary events that involve radical changes in body plans, developmental paths and metabolisms. In the more general case of complex systems, the movement across idea boundaries i.e. the de-territorialization and re-territorialization of ideas, as in the example of the wasp and the orchid, is what characterizes evolution from the perspective of the philosophy of becoming.

The connections thus made in regard to the evolutionary dynamics of complex systems are between the philosophical concept of becoming, the dynamic limits of diversity (that can also be considered as the contours of morphogenetic fields) and the more concrete concept of self-organization. The fourth important connection to be briefly discussed here is to the concept of singularity.

When we address the dynamics of systems, self-organization is indeed a useful concept to describe the spontaneous emergence of more ordered patterns of behaviour from less ordered ones. Technically, self-organization always involves the convergence of trajectories into more constrained subspaces of the system's state space (i.e. basins of convergence); in other words, the reduction in degrees of freedom of the said trajectories. For example, if all trajectories of a certain system tend to converge from a three-dimensional space into the surface of a two-dimensional torus, we will call it self-organization. As was already explained in Sect. 6.2, all such convergences involve singularities. The common textbook examples of point, cycle or toroidal singularities are deceptively simplified (Abraham and Shaw 1992). Multidimensional singularities may have complex shapes that we cannot possibly visualize. Every singularity possesses a so-called basin of convergence (or basin of divergence for unstable singularities) of a similar or higher dimensionality. Trajectories entering the basin of convergence will eventually converge into the singularity, as differences along some of their dimensions are gradually eliminated. Importantly, the multidimensionality of singularities also allows multiple levels of self-organization. For example, four-dimensional singularities can contain myriad three-dimensional ones and each of those can contain myriad two-dimensional ones and so forth.

What makes singularities important for the study of complex systems is the understanding that every repetition, every actual individuated instance involves a configuration of singularities. Singularities, according to the philosophy of becoming, are the significant elements of order but in themselves do not prescribe actual patterns. Only the configurations (distributions) of singularities within ideas (the ones being 'thought' by individuals) give rise to actual patterns, i.e. concrete manifestation of ideas. Remarkably, in the same manner that singularities are nested, so are ideas which give rise to intrinsic hierarchies.

The development of trajectories in the process of becoming is not necessarily towards the reduction of degrees of freedom (i.e. more determinations). Trajectories may gain additional degrees of freedom when an external perturbation drives the system's trajectory out

[41] The term basically means making the contour of the idea more distinct and definite. For example, if all the houses of a certain neighbourhood are painted with one distinct colour it makes this neighbourhood more territorialized. De-territorialization means the opposite: making the contour of an idea less distinct and definite.

[42] See Protevi (2012, pp. 251–254) on assemblages and niche construction.

[43] See Andriani and Cohen (2013) on the role of exaptation in biological and technological innovation.

of the basin of convergence of a singularity. Becoming, therefore, is not only a movement in one direction from the virtual to the actual. The intensities involved may drive an actual system towards a less organized phase or even alternately between more and less organized phases. While reaching less organized, de-territorialized phases, systems may form contingent assemblages with other systems and transform entirely their actual behaviour. De-territorialization tends, therefore, to encourage ideas to associate with each other in the thinking of individuals. In the new understanding of thinking developed by Deleuze every individual is a thinking subject. A thought can move in two major directions: towards actualization, which is a determining, symmetry-breaking movement, and away from actualization towards a less distinct and less individuated phase. The significant turns in the development of ideas are its movements through singularities where the limits of diversity change and ideas become more or less open to interactions (open to affect and be affected) with other ideas. The relation between ideas and singularities also suggests a novel, 'soft' distinction between the evolution and the development of ideas as the morphogenetic fields of actual patterns. Development involves movements within a multiplicity and preserves the configuration of singularities while evolution always involves the formation of new assemblages, which also affects the configuration of singularities within a multiplicity. The distinction is soft for two reasons: first, because it is said of virtual elements and not concrete individuals and second, because ideas do not have definite contours in the first place, just a range of affection.

In accounting for the full range of movements of the limits of diversity, the philosophy of becoming goes beyond cybernetics (Heylighen et al. 2007). Cybernetics is inherently biased towards processes of self-organization that by definition reduce the degrees of freedom of a system. These processes are automatically deemed more relevant because they produce concrete identifiable individuals that can be considered as products, goals, or even (in some distorted twists of reasoning) final causes. Likewise, every discipline of thought that presumes identities is biased towards the products of determinations, often overlooking how they come about. Hypotheses, theories and principles are always focused on highlighting invariants—those structural or behavioural aspects of systems that seem not to change. But if we are to extend our understanding of the 'not so well-behaving' systems—those systems that do not display obvious invariants if at all—we must go beyond the products of self-organization in order to account not only for the emergence of actual order but also for its dissolution and openness. We need to attend to the full movement, both converging to and diverging from actualized patterns, of the limits of diversity.

The above is just a brief exploration of how Deleuze's philosophy of becoming transforms the conceptual understanding of complex systems and their dynamics. As we witness the accelerating convergence of social, technological and biological systems at multiple scales it is clear that new trans-disciplinary methods are required to address the challenges that such open, heterogeneous and highly productive systems pose (Helbing 2013). The evolutionary ontology and the novel conceptual toolbox provided by Deleuze's philosophical programme seem to offer promising trajectories towards the creation of such methods.

9 Conclusion

The holy grail of classical science was always to come up with one elegant simple theory that would account for all phenomena. Unity and simplicity in unity were and still are the landmarks of scientific understanding in most fields. The power of a theory is measured by the variety of phenomena it is capable of subordinating under the same principle (i.e. the one identity). Such landmarks that guide scientific endeavours are grounded in the Platonist and Aristotelian systems of thought, which offer identity, immutable essences and transcendent laws as first principles. These principles also allude to a deeply rooted belief in a single creator or creative principle which is *outside* creation, and to a single unified observer, always located *outside* the observed happening. Both certainly resonate with man's dream of having complete knowledge and consequently complete control over nature.

The investigation of complex phenomena dealt a shattering blow to the worldview sustained by these principles. It is quite clear today that most phenomena, with few exceptions, can hardly be tamed by this philosophical paradigm and the science it engenders. In this sense the emerging science of complexity is far from being just another field of scientific research; it is rather a paradigmatic shift in scientific thinking and the philosophical principles that underlie it. The significance of complex phenomena is not in the general and universal principles that bring it forth but rather in the heterogeneous and unpredictable expressions of these principles. It is not the unity and uniformity which is interesting in complexity; it is uniqueness, variety and the manner individual phenomena emerge.

Systems theory—the major set of conceptual tools for tackling complexity, was developed within the ecology of thought of the twentieth century where ontology and its importance to the foundations of science were of little interest to, if not totally rejected by, the majority of prominent philosophers (Carnap 1996).[44] The theory was developed, therefore, as a tool of abstraction—a representational system that abstracts away physical matter and shifts emphasis from the study of phenomena towards the study of idealized representations of phenomena. Models are created to resemble the behaviour of physical systems, and their success is measured in terms of similarity. The differences between the model's behaviour and the corresponding real system are considered only as disturbing the established similarity. As such they need to be either eliminated by refining the model or disregarded as unimportant. The exclusion of difference is not a mere technicality; it is paradigmatic and in full conformity with the philosophical roots underlying classical Newtonian science. The attempts to establish an independent philosophical ground to systems theory mostly culminated in extreme relativism and constructivist theories (Heylighen and Joslyn 1992; Maturana 1988) that only reinforced the abstract idealistic nature of the theory.

It is in the light of this that the significance of Deleuze's philosophy of becoming is clearly apparent in *providing ontological grounding* to systems theory and the investigation of complex phenomena. It provides a coherent and plausible path towards a worldview that accommodates difference, variety, heterogeneity and process of change at its ontological level. This worldview brings both the creative process and the observer back into existence. Embracing the philosophy of becoming, we rediscover the *idea* as a creative element immanent in matter and not as the transcendent immutable element it is according to classical philosophy. Ideas as multiplicities are inexhaustible in their manners of actual expression in all phenomena and of course in our perceptions and thoughts. Thought as well as the subject of thought dynamically emerge through diverse interactions as individuated actual phenomena.[45] This goes a long way from the classical image of thought produced by a presupposed and unified observer by means of transcendental faculties or a privileged access to a plane

[44] Carnap and the Vienna Circle that operated in the 1920s had a tremendous influence on the scientific paradigm during the twentieth century.

[45] This involves of course a critique on the famous 'Cogito' with implications on the nature of 'self' and 'I': the thinker is individuated in thought always fragmented and incomplete.

of pure ideal essences. Distinct concepts, like any other phenomena, are individuations of ideas. While ideas as multiplicities are dynamically shaped by actual phenomena, concepts are actual expressions of ideas through becoming. However, with ideas being their virtual aspect, concepts are never complete final products.

The abstract concept of system as a structure independent of specific implementation is not eliminated but is radically transformed into the concept of multiplicity. Its externally imposed structural rigidity (as described in Sect. 2) is eliminated and it gains instead a much needed account not only of the lawful behaviour of actual phenomena but also of their inherent heterogeneity, incompleteness and unpredictable creative potential, all of which are particularly characteristic of complex systems. Systems theory, thus grounded in the virtual, will then be *presenting* existence instead of dealing with *representations* of existence. This is the core value of the paradigm shift spelled by the philosophy of becoming.

Clearly, Deleuze's work thus abridged is a valuable contribution to the foundations and philosophy of systems theory and scientific thinking. An objection that is often raised against this case is that Deleuze's work is obscure and basically anti-scientific. While the focus of science should be on explicating things and bringing to light the hidden principles that govern the world of phenomena, Deleuze's ontology makes the case for a dimension of existence which is intrinsically hidden and implicit. The virtual cannot be explicated and cannot be brought to the light of understanding. Processes which drive the individuation of phenomena will always have an obscure aspect. Such an approach cannot possibly support and benefit scientific thought. This objection fails to grasp the most fundamental thrust of Deleuze's work: the replacing of identity with difference as the primary ontological element. The Platonist and Aristotelian ontologies were constructed under the presumption that the elements of existence, or at least a more or less faithful copy of them, can be *entirely* grasped by the intellect. This presumption secures the primacy of both representation and reductionism as the main vehicles of scientific thought, i.e. it is possible to understand the world of phenomena in terms of representations of its elementary constituents and their relations. In claiming that the ontological elements of existence are ungraspable differences, Deleuze exposes the presuppositions at the basis of scientific thinking and highlights their serious limitations. Deleuze's approach is not anti-scientific. He only rejects dogma in science and convincingly suggests the need to reform and expand the foundations of science. Science as a paradigm is also the product of becoming—there must be more to it.

The fields of research that would be most impacted by introducing the concepts outlined here are obviously those where the failure of representation and reductionist methodology are most apparent. These include highly reflexive and novelty producing systems that are therefore difficult to model e.g. evolutionary systems, developmental systems, cognition, economic and social systems, quantum computing and many others. It remains for further research to find out whether the application of the philosophy of becoming to these fields will indeed yield new insights and novel methods of research.

Finally, in the context of how systemic thinking applies to human affairs, a short remark on the ethical aspect is in place: individuation and creative difference, the metaphysical watermarks of this philosophy, carry with them profound ethical implications that diverge significantly from mainstream thinking. In the fast-changing complex world we live in with its acute problems and the far reaching opportunities it presents, the philosophy of becoming rephrases the perennial question of how one should live into another one: how might one live (May 2005, pp. 1–25)? In this, it highlights a radically experimental and open-ended approach as a cure for dogmatic fixation in thought and action.

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Chapter 11

Synthetic Cognitive Development

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Synthetic cognitive development

Where intelligence comes from

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Abstract. The human cognitive system is a remarkable exemplar of a general intelligent system whose competence is not confined to a specific problem domain. Evidently, general cognitive competences are a product of a prolonged and complex process of cognitive development. Therefore, the process of cognitive development is a primary key to understanding the emergence of intelligent behavior. This paper develops the theoretical foundations for a model that generalizes the process of cognitive development. The model aims to provide a realistic scheme for the synthesis of scalable cognitive systems with an open-ended range of capabilities. Major concepts and theories of human cognitive development are introduced and briefly explored, focusing on the enactive approach to cognition and the concept of sense-making. The initial scheme of human cognitive development is then generalized by introducing the philosophy of individuation and the abstract mechanism of transduction. The theory of individuation provides the ground for the necessary paradigmatic shift from cognitive systems as given products to cognitive development as a formative process of self-organization. Next, the conceptual model is specified as a scalable scheme of networks of agents. The mechanisms of individuation are formulated in context-independent information theoretical terms. Finally, the paper discusses two concrete aspects of the generative model – mechanisms of transduction and value modulating systems. These are topics of further research towards an implementable architecture.

Introduction

A primary goal of artificial general intelligence (AGI) research is the synthesis of a machine capable of performing any intellectual task a human being is capable of and eventually going beyond that. While artificial intelligence research which is problem specific and context specific (e.g. understanding speech and text, visual pattern recognition, robotic motion, various optimization problems, etc.) has lately made quite a

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few impressive breakthroughs, artificial general intelligence research that aims to distill the principles of intelligence independently of a specific problem domain or a predefined context is still at its preliminary stages.

The goal of this paper is to present our approach to artificial general intelligence. We frame intelligence in the operation of cognitive agents. The intelligence of a cognitive agent is actualized as a set of competences enabling the agent to effectively respond to problematic situations presented to it by the environment in the course of their interactions. Normally, observing a cognitive system in its operation, we are able to identify a specific problem domain (e.g. motion in a 3D environment), extract the behaviors by which an agent addresses the problem, and create a model that represents these behaviors. The model, if successful, will capture the problem-specific intelligent mechanisms involved and will allow us to apply these mechanisms to similar problems. In such an approach, various organisms and primarily human agents are the exemplars and primary research subjects of intelligent behavior.

In our investigation, we realized that this approach meets its limits when we aim to understand how intelligent behaviors arise in the first place when an agent meets a problematic situation it has not encountered before and therefore does not possess the *a priori* knowledge of how to address it. Intelligent agents do not appear ready made. Human agents, as one remarkable example, undergo a prolonged and complex process of cognitive development till they become highly competent cognitive systems. If established cognitive competences and their entailed behavioral patterns are the actual manifestations of specific intelligence, it follows quite intuitively that the process of cognitive development by which such cognitive competences arise, is the fulcrum of general intelligence.

We argue, therefore, that the only effective way to understand general intelligence is by building a model of cognitive development. We describe an abstract genetic[1] process that can be applied to any general cognitive systems such as biological organisms, human agents, swarms, social systems, social institutions, robots, machine intelligences and more.

Here, we present a descriptive model that we aim to further develop in the future into a full generative one. The descriptive model provides the principles and conceptual framework of synthetic cognitive development. The goal of the generative model will be to apply our approach to the actual synthesis of systems capable of demonstrating cognitive development, i.e. operating general intelligence in an environment which is not *a priori* framed within a specific problem domain.

In the first section we specify our approach to cognition as the process of sense-making and identify major characteristics of cognitive development in human agents. In the second section we introduce Simondon's theory of individuation as the philosophical framework for our model. Using the theory of individuation, we depart from the specifics of human cognitive development and re-frame it in a general systemic context. The third section is a description of the conceptual model in information-theoretic terms. The final section outlines future research directions by discussing major components of the generative model.

1 Cognitive development and sense-making

The human mind is an exemplar of a cognitive system exhibiting a high degree of generality in its intelligence. In this section we aim to extract general principles of cognitive development from research areas such as psychology, cognitive science, neuroscience, social psychology, etc.

[1] Genetic in the sense of genesis.

Table 1. Era I (age 0-2): The era of sensorimotor intelligence. Adapted from (Kohlberg and Gilligan 1971, p. 1063).

Stage 1.	Reflex action.
Stage 2.	Coordination of reflexes and sensorimotor repetition (primary circular reaction).
Stage 3.	Activities to make interesting events in the environment reappear (secondary circular reaction).
Stage 4.	Means/ ends behavior and search for absent objects.
Stage 5.	Experimental search for new means (tertiary circular reaction).
Stage 6.	Use of imagery in insightful invention of new means and in recall of absent objects and events.

1.1 Human cognitive development

The concept of cognitive development has been defined in the field of psychology as "the emergence of the ability to understand the world" (Schacter et al. 2010, p. 447). Traditionally it is mostly associated with the child development stages proposed by Jean Piaget but can be also applied to describe sense-making by an individual throughout its whole lifetime as proposed by Kegan (1982). Piaget originally contended that children pass through four eras of development – sensimotor, prelogical, concrete operational, and formal operational – which can be further subdivided into stages and substages (Kohlberg and Gilligan 1971; piaget 2004) (see Table 1). Kegan also propounded that Piaget's and some later cognitive development theories generally describe recursive subject and object relationships when the subject of previous stage becomes an object in the next stage, to which he refers as an "evolution of meaning". Subject in this context means whatever is perceived as part of self while object is part of environment. Therefore cognitive development can be understood as *an ongoing balancing of subject – object relations and interactions across the emerging boundary of an individual towards increasing cognitive complexity*[2]. This recursive process progressively defines a boundary of an individual – a psychic differentiation of *self* from the *other* (Kegan 1982, p. 24) which generally constitutes the differentiation between agent and environment.

For further clarification of our understanding of cognitive development as individuation and the benefits of such an approach, let us examine a schema of Era I of early cognitive development as formulated by Piaget (Table 1). It is clear that every subsequent stage builds upon the previous one and together they seem to form a hierarchy. It seems however that cognitive development theorists and practitioners, including Piaget, agree that stages in cognitive development overlap, occur in parallel or get manifested later in the maturation process. Therefore we can approach the process of cognitive development as both a sequence of stages and a continuum. In the next section we will see that a developmental continuum punctuated by distinct stages is also supported by understanding cognitive development as a case of individuation. The appearance of stages of cognitive development seems to be better understood in terms of products of individuation or 'evolutionary truces' as Kegan calls them.

1.2 Enaction

The enactive approach treats cognition as the adaptive process of interaction between an agent and its environment. The distinction between agent and environment is

[2] We formally define the general characteristic of operational complexity of an agent in 3.4. Cognitive complexity is an operational complexity *in the context of a cognitive system* characterizing the coupling of internal complexity of a cognitive agent with its environment.

constituted by the interactions themselves. We define a *cognitive system* as a complex adaptive system which is an organized network of interactive sub-processes De Jaegher and Di Paolo 2007, p. 3) that together realize a network of objects and their relations as they are perceived in the world.

A cognitive system cannot form itself separately from the matrix of interactions with other entities within a larger population. In terms of social psychology this principle is informed by a perspective that minds exist only as social products (Summers 1994, p. 328). Relationships and bonds with other entities of the population are part of the cognitive system and thus define its identity on equal terms with internal relationships and structures. Therefore, the mental states of an individual are not established prior to the interaction, but are shaped, or even created, during its dynamics. Di Paolo and De Jaegher (2012) describe these dynamics as participatory sense-making and propose what they call the "Interactive Brain Hypothesis" which "describes an extreme possibility, namely that all social brain mechanisms depend on interactive elements either developmentally or in the present, even in situations where there is no interaction" (Di Paolo and De Jaegher 2012, p. 5).

Also in some forms of psychotherapeutic theory and practice (e.g. Gestalt, the interpersonal approach to psychoanalysis), certain interactions or situations which are normally considered external to an individual are actually an integral part of its sense-making processes. An individual enacts itself in its social milieu rather than merely using internal representations, plans or theories of mind or even perceptual routines existing prior to the interaction.

Edelman and Mountcastle (1982) define "world inputs" and "self-inputs" to differentiate between interactions across and within the boundary of a neuronal group. We extend this principle from the context of neuronal groups to networks of cognitive agents. An individual is defined as a totality of both types of interactions while the proportions of them may differ at different periods.

1.3 Sense-making

Sense-making is one of the components of the enactive approach to mind and cognition (De Jaegher and Di Paolo 2007, p. 3). We understand cognition as a process of individuation within a scope referred to by piaget (2004) as "genetic epistemology". A psychologically oriented definition of sense-making is: *sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively in relation to them* (Klein et al. 2006, p. 3). From the perspective of dynamics of the cognitive system as defined by us, sense-making is continuous effort to form a network of connections and objects as they are perceived in the world. The enactive approach implies that cognition and sense-making are seen not as something that happens inside clearly defined boundaries of the cognitive system but are the product of interactions (McGann 2008, p. 1) across emerging boundaries: "Sense-making establishes a perspective on the world with its own normativity, which is a counterpart of the agent being a center of activity in the world" (De Jaegher and Di Paolo 2007, p. 4).

In the context of cognitive development, sense-making has the following notable aspects:

- **Identity and identification** – A prior notion of an entity "which is making sense" seems to be needed, but in our framework it is not the case: the identity of cognitive agents is created during the process.
- **Enaction** – According to Clark (2012, p. 6) perception is an action where an agent produces a stream of expectations and then corrects its own model according to incoming information. Therefore the primary component of sense-making is an

action: an agent acts upon the environment, catches the "reflection" or response and updates the internal representation of it.
- **Reflexive** – Sense-making is a two-way interaction between the individual and its environment across the boundary being created during the same process: any agents' examination, modeling and action 'bends' the environment and affects the perception of and further decisions by those same agents. The property of reflexivity of the system captures these mutual influences of networks of processes across the boundary of an agent.
- **Participatory aspect** – As noted by De Jaegher and Di Paolo, "mental states that "do" the understanding and the ones to be understood are not fully independent or established, but are instead affected, negotiated, and even created as a result of interaction dynamics" (Di Paolo and De Jaegher 2012, p. 4). They describe the set of possibilities arising from these dynamics with the notion of *participatory sense-making*, emphasizing its social aspect. In Sect. 3 we extend the social aspect of sense-making across multiple scales (Fig. 2).

1.4 Cognitive dissonance

The approach to cognitive development as a sequence of integration and disintegration cycles of meaning is supported by several theories. Leon Festinger's theory of cognitive dissonance, developed in the 1950s, focuses on a state of mind holding two or more elements of knowledge which are relevant but inconsistent with each other Harmon-Jones (2012). It is arguably a normal state of an intelligent agent engaged in a life-long activity of making sense of its environment. The theory proposes that incompatibility of the elements create a state of discomfort or "dissonance" which is proportional to the degree of incompatibility – the lack of integration. Further Festinger hypothesized that persons experience an arousal – usually unpleasant emotions – due to the dissonance which motivates them to engage in "psychological work" to reduce the inconsistency. Cognitive dissonance theory in its original form generally enjoys experimental support. Particularly interesting are experiments showing that during the state of dissonance individuals evidence arousal and report negative affect (Harmon-Jones 2012, p. 2). Studies in cognitive neuroscience indicate a tendency of a cognitive system to choose a single explanation of sensory experience by constraining multiple possibilities, thereby reducing internal uncertainty or dissonance. For example, the entropic brain hypothesis of Carhart-Harris et al. (2014) points to the association between perception of identity and organized brain activity. The dynamic core hypothesis of Edelman and Tononi (2000) likewise connects concepts of immediate consciousness with synchronized activity of neuronal groups and areas in the neocortex.

These observations fit the sense-making concept indicating a tendency of the cognitive system towards increased coherency both internally and in its relationships with the environment. Nevertheless periods of reduced coherency are necessary for the cognitive system in order to explore possibilities of the higher coherency – what we call *cognitive complexity* in Figure 1.

1.5 Arousal and emotion

Contrary to the established scientific opinion of the end of 20$^{\text{th}}$ century, feelings and emotions are just as cognitive as any other percepts (Damasio 2008, p. 16) and their role cannot be overlooked when considering the development of a cognitive system. While currently the importance of emotions and feelings for the overall operation of a cognitive system is increasingly accepted, the integration of an "emotional system" into the model of cognition is still problematic. (Damasio 2008, p. 284) proposes a view of emotions as an immense collection of changes occurring in both brain and body, usually prompted by particular content while feeling as the conscious perception of those changes. This proposal is strikingly similar to the two-factor theory of emotion by Schachter and Singer conceptualizing emotion as general arousal plus a cognitive label attached to it (Cooper 2007, p. 58). The state of arousal starts a chain of events within an organism which usually leads to the decrease of arousal. These events can take a form of internal "psychological work" Harmon-Jones (2012) or external actions in the environment, both of which can be considered as sense-making activities. Further, Damasio (2008) differentiates between *primary emotions* and *secondary emotions*. Primary emotions are "wired from birth" and constitute what is understood as drives and instincts. Secondary emotions are acquired by creating systematic connections between primary emotions and categories of objects and situations (Damasio 2008, p. 151).

1.6 The scheme of cognitive development

Based on concepts discussed in this section we propose a scheme which conceptualizes cognitive development as an observable sequence of integration and disintegration processes progressively determining the cognitive complexity of an agent. The progressive nature of cognitive development is manifested by *increasing the capacity of sense-making*. This process does not follow a trajectory of monotonous adaptation but rather advances in a punctuated manner going through relatively stable stages. The enactive nature of sense-making implies a reflexive relation between system and environment. At every state, both the cognitive system and the environment have more than one option to relate to each other. Therefore every state of the interaction is characterized by a unique trade-off between freedom and constraints in choosing future trajectory development. Additionally, system–environment boundaries are themselves subject to variation. We suggest that this freedom–constraint trade-off in humans is closely associated with the level of experienced cognitive dissonance. The system achieves higher levels of cognitive complexity via periodic fluctuations in its level of cognitive dissonance. When the cognitive dissonance of the system is low, it undergoes constrained periods of development with more predictable developmental trajectory. When cognitive dissonance is high, the future trajectory of the system becomes more divergent. Our hypothesis is that emotions are mechanisms that guide the selection of the developmental trajectories of the cognitive system by modulating the sensitivity of the system to environmental stimuli. We generalize these mechanisms in our synthetic cognitive development model by introducing value systems that modulate the global developmental activity.

Figure 1 is a scheme of cognitive development as a variation of cognitive dissonance versus coherence of a system which can be mapped to certain cycles. These cycles emerge from the attempt to balance opposing tendencies to suppress the unpredictability of the cognitive system on the one hand and keep it open to change on the other.

Human cognitive development is usually understood as a predictable and finite sequence of developmental stages. We argue that both the predictability and finiteness of cognitive development are not ingrained or necessary properties of the process but rather constitute historically shaped superficial characteristics. For example, the relative stability of observable stages of child development are related to more or less stable external influences of parents, peers and society as well as to genetic predispositions. Likewise, the fact that mature individuals rarely undergo transitions to higher

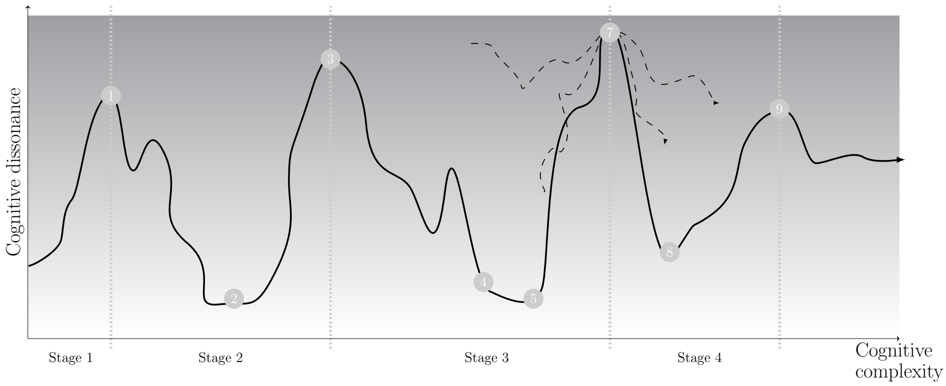

Fig. 1. A scheme of cognitive development qualitatively visualizing the dependency of increasing cognitive complexity on the variation in the level of cognitive dissonance of a system. The bold curve represents actual developmental trajectory. Circles with numbers represent states of development, arbitrarily chosen for illustration. States (1), (3), (7) and (9) mark high cognitive dissonance states where the system has the highest possibility of "choice" between alternative developmental trajectories. Dashed lines are drawn at stage (7) to illustrate multiple possible trajectories that are actually present at every point along the developmental trajectory. States (2), (4), (5) and (8) mark stable periods when the operation of a cognitive system is constrained. Stages 1, 2, 3 and 4 on the horizontal axis illustrate cognitive development stages as described by the developmental psychology representing punctuated manner of increase in cognitive complexity.

levels of cognitive development is possibly related to reduced environmental pressures to engage in the "psychological work" involved. The rationale of seeing cognitive development beyond its observable predictability and finiteness is instrumental for the framework of synthetic cognitive development which aims to describe the genesis of a general cognitive agency as a continuous individuation process, which is the focus of the following section.

2 Cognitive development and individuation

Following the embodied-enactive approach in its broadest sense, cognition is the bringing forth of a world of objects and entities and the relations among them. Bringing forth a world is first and foremost about interacting in it. Perception, action, thought and other cognitive activities are only aspects of this all-encompassing interaction. We can say that cognition, therefore is the bringing forth of individuals, both subjects and objects, and their relations. What an individual is and how individuals come into existence are questions that we address in the context of understanding cognition and cognitive development. As a starting point, an individual is known by that property(ies) or quality(ies) by virtue of which it is unique or describable as such. What define individuals therefore, are distinctions and boundaries the formation of which is a primal activity that precedes even the notion of individual. The nature of distinctions and boundaries is subtle; inasmuch as they separate subject from object, figure from background and one individual from another, they must also connect that which they separate. A boundary, therefore, is not only known by the separation it establishes but also by the interactions and relations it facilitates.

Following the premise that cognition is the bringing forth of individuals, our interest in cognitive development led us to the interesting conjecture that cognitive development can be understood in terms of how individuals come into existence in the first place, or in other words, to their individuation. As we aim to establish principles of synthetic cognitive development, we find this shift in focus from individuals to individuation; from given identities to their generative processes, both necessary and philosophically profound.

2.1 Individuation – a brief philosophical introduction

To have a preliminary grasp of the concept of individuation, we need to briefly review the importance of individuals in the way we describe the world. The philosophical tradition that started in ancient Greece, and particularly with Aristotle's metaphysics, sees the world as made of individual beings with a given stable identity. What defines an individual is a set of stable qualities. The principle of the excluded middle posited by Aristotle ensures that an individual cannot possess a certain property while simultaneously not possess it. Hence, the identity of individuals, according to Aristotelian theory, is unambiguously defined. To account for the genesis of individuals, according to this theory, we need to identify a principle(s) and the specific initial conditions of its operation that together bring forth the individual. For example, planet earth is an individual object. To account for its individuation, astrophysicists have come up with a theory about the formation of planets and the necessary conditions for planets to form, i.e. the existence of a star such as the solar system. Inasmuch as this scheme makes sense, it suffers a major weakness: it only shows how individuals (planets) are formed from other individuals, i.e. certain necessary conditions that are given *a priori* and an individual principle – a stable theory of planets formation – being followed. Clearly, in the very way we commonly think, individuals are primary ontological elements and individuation is only secondary (Weinbaum 2015). From the Aristotelian theory of individuals, it follows therefore that we must always assume a fully formed individual prior to any individuation. This theory, however, is not very helpful for generalization of our scheme of cognitive development.

Gilbert Simondon was the first to criticize in depth the classical treatment of individuation and the majority of his writings (Simondon 2005) are dedicated to developing a new philosophy of individuation. In Simondon (2009) he explains:

> "Individuation has not been able to be adequately thought and described because previously only one form of equilibrium was known–stable equilibrium. Metastable equilibrium was not known; being was implicitly supposed to be in a state of stable equilibrium. However, stable equilibrium excludes becoming, because it corresponds to the lowest possible level of potential energy; it is the equilibrium that is reached in a system when all of the possible transformations have been realized and no more force exists. All the potentials have been actualized, and the system having reached its lowest energy level can no longer transform itself. Antiquity knew only instability and stability, movement and rest; they had no clear and objective idea of metastability."

In Simondon's new theory of individuation, we are encouraged to understand the individual from the perspective of the process of individuation rather than the other way around (Simondon 1992). The individual is a metastable phase in a process and is always in possession of not yet actualized and not yet known potentialities of being. Simondon adds:

> "Individuation must therefore be thought of as a partial and relative resolution manifested in a system that contains latent potentials and harbors a certain incompatibility within itself, an incompatibility due at once to forces in tension as well as to the impossibility of interaction between terms of extremely disparate dimensions."

According to Simondon, an individual is not anymore a rigid unity with ultimately given properties but rather a plastic entity in a metastable state punctuated by events of transformation. Every such event reconfigures the system of tensions and the manner by which they will determine further transformations. This description is aligned with our understanding of cognitive development as the continuous resolution of cognitive dissonance (see 1.6).

2.2 The preindividual

In their process of individuation, individuals are not preceded by already individuated entities or principles that instruct the trajectory of their formation but by a state of affairs which is yet undetermined – the *preindividual*. Even after an individual has reached a relatively stable state, the preindividual is not exhausted and persists in the individual. This is what allows its subsequent individuation or becoming. The unity characteristic of fully individuated beings (i.e. identities) which warrants the application of the principle of the excluded middle, cannot be applied to the preindividual. The preindividual goes beyond unity and identity. Deleuze, whose seminal work *Difference and Repetition* draws on many of Simondon's insights, would later describe the preindividual as "determinable but not yet determined" and individuation basically proceeds as its "progressive determination" (Deleuze 1994; Weinbaum 2015).

Simondon also emphasizes that relations between individuals undergo individuation too: "A relation does not spring up between two terms that are already separate individuals, rather, it is an aspect of the *internal resonance of a system of individuation*. It forms a part of a wider system." (Simondon 2009, p. 8). In particular, individuation never brings to light an individual in a vacuum but rather an individual-milieu dyad. This dyad contains both a system of distinctions and a system of relations. The individual and its milieu reciprocally determine each other as they develop as a system wider than the individual.

2.3 Metastability

Understanding Simondon's concept of the preindividual – the dynamic situation that both precedes and is immanent to individuals – is based on his particular notion of metastability. In systems dynamics, the system's states can be mapped into an energy plane where each state is represented by a point on a N-dimensional plane and is assigned a scalar number designating the energy of the system at that state. A stable state of the system is a state characterized by low energy value relative to neighboring states. If the system is perturbed from a state of stability it will often (depending on the size of perturbation) reach a state of slightly higher energy and will tend to immediately return to the initial state of lower energy. A metastable system is normally a system with a few local minima. Given strong enough perturbations a metastable system may move among states of local stability and hence the designation that implies that no single state is truly stable. It is easy to notice that the topography of the energy landscape here is given and the system dynamics only moves among the already determined set of stable states. Clearly, this representation will only fit an already individuated system. Simondon's notion of metastability departs from this scheme in that the relations between variables in a preindividual condition are not yet determined and the whole landscape is dynamic. As the individuating system moves from state to state, the topography of the landscape changes and may settle into a stable shape only as the state variables mutually determine their relations[3].

[3] This settlement is also mentioned in an above quote as the resolution of incompatibilities.

Importantly, the dynamics of a metastable system is not determined *a priori* but rather individuates along with its structure in a sequence of transitions.

2.4 Transduction

One of the most significant innovations in Simondon's theory is the concept of *transduction*. Transduction is the abstract mechanism of individuation, an activity which takes place in the preindividual. Classical logic and procedural descriptions cannot be used to think about individuation, because they require the usage of concepts and relationships among concepts that only apply to the results of the operation of individuation (Simondon 2009, p. 10). Transduction comes to designate, therefore, a new model of thought that is constructed from a genetic (as in "genesis") point of view. Combes and LaMarre (2013) writes: "Simondon "transgresses" the Kantian limits on reason.[...] Such an approach appears to offer a reinterpretation of the thesis of Parmenides, wherein "The same, itself, is at once thinking and being" [...]." That thought and being (in the sense of individuals brought forth) are considered the same from the standpoint of the mechanism of individuation, highlights how transduction presents a significant contribution to the philosophical understanding of cognitive development. Cognitive development is a formative process where both subject and object are individuated. This individuation produces knowledge – a resolution, at least a partial one, of an incompatibility (i.e. unresolved tensions) which preexists subject-object differentiation. For Simondon, the conditions of knowledge and of cognition are not given a priori. We can therefore conceive of cognitive development without any inherent limits.

Simondons adds on transduction: "One could, without a doubt, affirm that transduction cannot be presented as a model of logical procedure having the value of a proof. Indeed, we do not wish to say that transduction is a logical procedure in the current sense of the term; it is a mental process, and even more than a process, *it is a functioning of the mind that discovers* [emphasis added]. This functioning consists of following being in its genesis, in carrying out the genesis of thought at the same time as the genesis of the object." (Simondon 2009, p. 11) (see also p. 254 below).

It is beyond the scope of this article to provide an in-depth review of transduction – especially of its psychic and social dimensions – but we will give here the highlights that are essential to our approach to cognitive development. Simondon initially defines the concept as follows:

> "By transduction we mean an operation–physical, biological, mental, social–by which an activity propagates itself from one element to the next, within a given domain, and founds this propagation on a structuration of the domain that is realized from place to place: each area of the constituted structure serves as the principle and the model for the next area, as a primer for its constitution, to the extent that the modification expands progressively at the same time as the structuring operation. A crystal that, from a very small seed, grows and expands in all directions in its supersaturated mother liquid provides the most simple image of the transductive operation: each already constituted molecular layer serves as an organizing basis for the layer currently being formed." (Simondon 2009, p. 11)

Here are a few points that can be extracted from this definition:

The dynamics of transduction – Clearly, transduction is reminiscent of the concept of self-organization both in its reference to stability and metastability and in the emergence of structure in a process of relaxing a system of tensions[4]. Individuation will take place as long as the system has not reached a final stability and exhausted its potential for change. But in fact final stability is only an idealization because it requires a closed system that does not interact with its environment, or is not distinct from its environment (thermodynamic equilibrium). Open systems that maintain at least some distance from equilibrium, or are far from equilibrium, like living organisms and ecosystems, can be considered as continuously individuating. Transduction, however, goes further than the formal understanding of self-organization in addressing complex situations that are more difficult to represent in terms of energy or information exchanges. While self-organization commonly describes the convergence of trajectories towards attractors within an already configured state-space, transduction does not presume such an *a priori* configuration that is characteristic only of already individuated systems.

Transduction is said to take place when two systems which are initially incompatible come to interact with each other. Simondon uses two terms to explain incompatibility or unresolved tensions: the first is *disparity* which refers to two elements that initially do not share any common ground. The second term is *problematic* in the sense that two systems pose a problem for each other that needs some resolution. For example: the problem the environment poses for an organism which requires it to either adapt or change the environment. The resulting interaction is a transductive process that drives the individuation of both organism and environment. In the course of their interactions, the outcome of which is initially undetermined, they form certain relations of resonance or reciprocal determination by one constraining the dynamics of the other. When such process achieves a relative stability an organization or a structural pattern emerges as the individual. Both initial systems have changed and they now present a pattern of (more or less) regulated interaction that also highlights a distinct boundary. This resolution however is never complete. The remaining unresolved aspects of the interaction are those that maintain the preindividual being within the formed individual and will eventually drive further individuation.

Structure and operation – Perhaps the most important aspect revealed in transduction is the progressive co-determination of structure and function (see also above regarding the notion of metastability). Individuation can be seen as a chain of operations O on structures S: $S \to O \to S \to O \to S$... (Combes and LaMarre 2013, p. 14, 15). Every operation is a conversion of one structure into another, while every structure mediates between one operation and another. Each structure in the chain constrains the operations that can immediately follow. Each operation can transform the previous structure into a limited number of new structures. Every intermediate structure is a partial resolution of incompatibility but it is driven away from its relative stability as long as the existing tensions are not exhausted. This is reminiscent of the propagation of a computation in evolutionary programming. Executed code and the data are analogous to operation and structure. But the code itself is also data that can be progressively modified to produce inexhaustible variety and innovation. This analogy helps us understand how operation and structure are reciprocally determining expressions of the transductive process.

Transduction and information – Simondon's concept of information is substantially different from that of Shannon's theory of information (Shannon 2001). Shannon's model of communication seeks to reproduce "at one point either exactly or approximately a message selected at another point." For this, one must

[4] We use here tension (or intensity) as a general term for energetic differences that drive structural and state changes in a system. See DeLanda (2013, Chap. 2).

presuppose an agreed upon system of encoded messages and the means of their exchange that is already individuated. Simondon's information precedes the individual. He seeks to describe information itself as existing in a state of metastability and indeterminacy. According to him "information must never be reduced to signals" but instead, must express the compatibility of two disparate realms (Iliadis 2013). The partial compatibility or coherence that is achieved during transduction is expressed as the emergence of information in the sense of mediating forms or operations. In Simondon's words:

> "Information is therefore a primer for individuation; it is a demand for individuation, for the passage from a metastable system to a stable system; it is never a given thing. There is no unity and no identity of information, because information is not a term; (...) Information can only be inherent to a problematic; it is that by which the incompatibility of the non-resolved system becomes an organizing dimension in the resolution; (...) Information is the formula of individuation, a formula that cannot exist prior to this individuation. An information can be said to always be in the present, current, because it is the direction [sens] according to which a system individuates itself." (Simondon 2009, p. 10).

In the context of cognitive development, the individuation of objects necessarily entails the individuation of exchanged signals and their signification across different scales of organization.

Transduction and logic – To further highlight the ontogenetic characteristic of transduction, Simondon compares the process to the logical operations of both deduction and induction. Transduction is not deductive since it does not posit a given principle(s) or pattern(s) external to the process that can instruct the resolution of the present situation. Deduction can only highlight that which is already given by fully individuated knowledge. Transduction discovers relations that did not exist before. Furthermore, transduction is not inductive in the sense that it does not extract those aspects of the incompatible terms that are nevertheless common to them, thereby eliminating what is unique to them. Instead, "[T]ransduction is, on the contrary, a discovery of dimensions of which the system puts into communication [...] each of its terms, and in such a way that the complete reality of each of the terms of the domain can come to order itself without loss, without reduction, in the newly discovered structures." (Simondon 2009, p. 12) Transduction, therefore, is a real resolution of difference through mediation and not reduction to some common denominator. Following this understanding, we argue that cognitive development is beyond what is reachable by a deterministic logical process. Only after we make sense of something can it become available to the faculties of rational thinking.

3 Cognitive development in information-theoretic terms

To substantiate our approach to synthetic cognitive development as a process of individuation, the goal of this section is to describe a conceptual model of self-organized boundary formation. We use an information theoretic approach to formalize the dynamic emergence of agents. For the sake of clarity of description, some of the terms here are didactically described from the perspective of an external observer. For example, we describe a distinction between an agent and its environment, or assume distinct states in the operation of agents prior to specifying how such distinctions arise in an actual process of individuation. Such descriptions are not instrumental to the actual processes; they are given only as a necessary descriptive scaffolding.

3.1 Concepts and terms

Agents and boundaries

Let us first consider a heterogeneous population P of N agents that are capable of exchanging information via interconnections. Each agent has a set of input and output connections to other agents so that they together form a network which reflects a topology of information exchanges. For simplicity we assume for the moment that each agent realizes a state machine with an internal state and input and output vectors. Input information is processed depending on the current internal state to produce an output and possibly change the internal state of the agent. We also assume that all the agents in the population are relatively stable in their behavior. As will become clearer in the following, the state machine description of the agent is only a schematic representation and does not reflect the actual structure of the agent.

In the course of individuation, P is differentiated by self-organizing into two subsets U and E. The subset U operates in relation to subset E as an environment that provides a repertoire of changing signals. Some of the agents in U can sense changes in the environment E (sensors) while others can introduce effects in the environment (actuators). As we consider self-organized boundary formation, prior to such formation, P is a pre-individual undifferentiated population. The division of P into U and E is in fact the product of an actual individuation process which will be specified by a complementary generative model. Here we only specify the initial and final stages of the process.

Heterogeneity and redundancy of P

The agents of population P are heterogeneous and redundant. Each agent in the population receives input signals and produces output signals that depend on its inputs and internal state. The transfer functions (i.e. input/output relations) of agents form a continuum of behaviors which account for the heterogeneity of the population. In addition to the variety of behaviors, there is an additional variety in the way each behavior is realized by agents with similar transfer functions. This accounts for the population's redundancy. Seen by an external observer, the behaviors of agents can be loosely classified into various functions such as sensors, actuators, filters, integrators, logical gates etc. But as our model focuses on individuation, the particular transfer functions do not matter. What matters is the generative process that organizes the population or parts of it into a coordinated whole where distinctions and coherent relations emerge. Both the heterogeneity and redundancy of the population are essential to the selective mechanisms that drive the process of individuation and will be further discussed in Sect. 4.

Individuation

Our goal is to model cognitive development as the process of individuation described in Sect. 2. Specifically, we aim to model the process by which a subset U of P self-organizes and differentiates itself from $E = P - U$ thus giving rise to a boundary and an individual–milieu distinction. The outcome of this process is a new individual agent[5] A whose function is realized by the coordinated and synchronized operations of its constituent agents belonging to U that are reciprocally selected from P. The term

[5] In the following it will become clear that more than one integrated agent can emerge in the process.

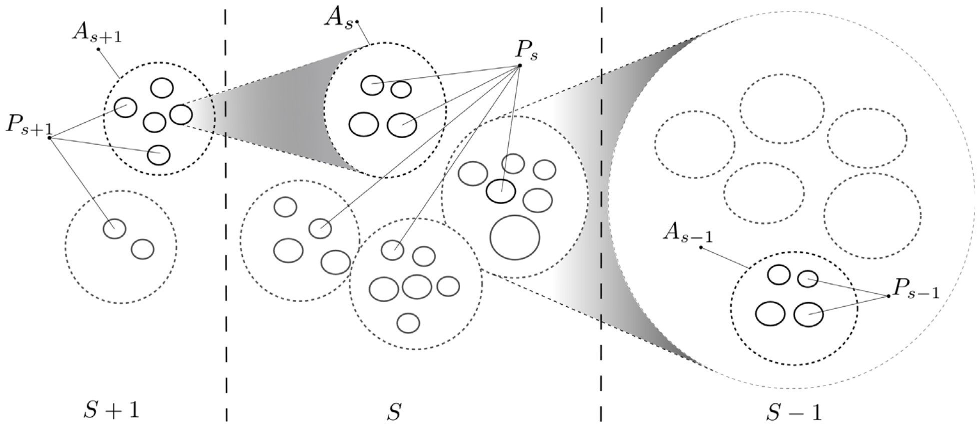

Fig. 2. Relationship among scales, populations and boundaries in the model. The chosen scale of analysis is S. $S+1$ is the higher scale while $S-1$ is the lower scale. P_s denotes a population of agents at scale S. Solid circles denote the agents of population P at any scale. Dashed lined circles denote super-agents at any scale e.g. – A_s at the center of the figure, denotes a super-agent that emerges from the interactions of agents in P_s. Super-agents at scale S are the agents of the population P_{s+1}. The $i-th$ super-agent at scale S is denoted A_s^i, the superscript is omitted if unneeded. Also, the subscript S is omitted from A or P in the text if it is redundant.

reciprocally selected here means that agents in the population spontaneously select each other, as they interact, to form coordinated coalitions without the intervention of an external guiding agency. As already mentioned in Sect. 2, the produced individuals are never final products. Changes in the environment may bring about changes in the structure and function of the emergent agent. Moreover, every such agent A, once emerging, may disintegrate altogether. That is why the stability of the structure and function of agents in our model is only a relative stability. In fact, all agents are dynamic constructs.

Scales of individuation

In our model, individuation is a scalable process that takes place at multiple scales, both structural and functional, of the individuating system. We describe the model at some scale S, where we observe a population of agents P_s. Every agent in P_s is a product of self-organization of simpler agents at the lower scale $S-1$. Similarly, super-agents A_s^i that emerge at scale S are the elements at the higher scale $S+1$. The individuation of agents, therefore, is taking place simultaneously at multiple scales. In most cases, lower scale agents must have more stable properties than higher scale agents. Instability of agents at lower scales would make higher level organization much less probable.

Scales differ not only structurally but also temporally. As the cognitive system individuates, complex objects emerge and their frequency of interactions become slower in comparison to their lower scale components. Generally, therefore, the relative frequency of interactions at scale S is slower than the rate of change at scales lower than S and faster than the frequency of interactions at scales higher than S. It is helpful, therefore, to understand the time scale associated with population P_s as the average duration of interactions within the population.

Following Simondon's understanding of information (see 2.4), as new individuals A_s^i emerge at scale S, new information is being created. This information is expressed in the structural and functional distinctions that become apparent at that scale. Whatever remains incompatible among the agents of the lower scale does not get expressed in the emergent new structures. Across multiple scales of individuation, these incompatibilities remain as the preindividual in their respective scales.

As we will see in 3.4, the emergence of a new individuated organization at scale S is accounted for in the reduction of entropy at the lower scale. But the new individuation(s) do not correspond to merely the entropy now calculated at a higher scale, but to the internal complexity C_{intrn} expressed in Eq. (6). The reason behind this difference is that the new individuals at scale S retain some incompatibility which is not resolved. They are therefore not ultimately organized, thus exhausting any further individuation. C_{intrn} takes into account the actual compatibility (in terms of mutual information) between the constituting agents and not merely the maximal repertoire of states they can present. This "internal coherence" expressed by C_{intrn} can indeed be associated with the amount of preindividual information that turns into a new individuated form.

3.2 Definition and formation of boundaries

In our model, the boundaries defining the agent – environment distinction and the relations between them – are never entirely fixed. The functioning of any emergent agent is adaptive and subject to changes. We follow the work of Giulio Tononi and his concept of *information integration* to formally define coordinated clusters in networks of interacting agents (Edelman and Tononi 2000; Tononi 2004, 2008). The reasoning behind the concept is that if we examine a population P of p_i interconnected agents, where $i \in [1, .., N]$, we wish to quantify how much they affect and are being affected by each other. In information theoretic terminology, each agent p_i can either change its state independently of all other agents in P, or its state may depend on the states of other agents in P, or even be entirely determined by the states of other agents. The mutual information between two agents p_i, p_j is given by the formula:

$$MI(p_i, p_j) = H(p_i) - H(p_i/p_j) = H(p_j) - H(p_j/p_i) \tag{1}$$

$$= H(p_i) + H(p_j) - H(p_i, p_j). \tag{2}$$

Where $H(x)$ is the entropy involved in the state of agent x. If p_i and p_j are independent, $H(p_i, p_j) = H(p_i) + H(p_j)$ and then $MI(p_i, p_j)$ would be 0. The mutual information would be maximum in the case that the state of one agent is fully determined by the other. In this case the mutual information will be equal to $min(H(p_i), H(p_j))$.

For a set of agents p_i in P the integration of the whole set would be given by the sum of the entropies of the independent agents p_i minus the entropy of the joint set P:

$$I(P) = \sum_{i=1}^{k} H(p_i) - H(P). \tag{3}$$

In order to compare the degree of integration within a subset of agents to the integration between the said subset and the rest of the population, we divide the population of agents P into two subgroups of differing sizes: X_i^k and its complement $P - X_i^k$, where k is the number of agents in the subset X. The mutual information between X_i^k and its complement is:

$$MI(X_i^k, P - X_i^k) = H(X_i^k) + H(P - X_i^k) - H(P). \tag{4}$$

Formula 4 measures the statistical dependence between a chosen subset i of k agents and the rest of the population. The *Cluster Index* CI of the subset X_i^k will therefore be given by:

$$CI(X_i^k) = I(X_i^k)/MI(X_i^k, P - X_i^k) \tag{5}$$

CI measures the degree of distinctiveness of a subset of agents in P compared to the whole population in terms of information exchange[6]. For $CI \leq 1$ there is no significant distinctiveness while a subset with $CI \gg 1$ indicates a distinct integrated cluster.

Equipped with this comparative measure, we can compute the subset $X^{k_{max}}$ of maximal size $k_{max} < N$ in P with the highest cluster index that *does not include subsets with a higher cluster index*. This subset will be designated as the primary functional cluster $PFC_p(t)$ of population P at time t. The primary functional cluster corresponds to the super-agent A, while the set of its constituent agents corresponds to U (see 3.1). The definition of functional clusters makes concrete the differentiation between an agent and its environment. Considering the relevant rate of information exchange in the population P, the computation involved can repeat itself in appropriate time intervals to yield a time series of PFCs. In other words, the boundaries of the primary functional cluster of P and the particular agents participating in it vary in time.

3.3 The dynamic core

The time-dependent primary functional cluster $PFC(t)$ will be the one corresponding to the super-agent A brought forth by P. The dynamic entity thus created was termed by (Edelman and Tononi 2000, Chap. 12) the *dynamic core*. However, our usage of the term is not confined to modeling the central nervous system. In the simplified case above we consider that P produces at any given moment only a single super-agent but clearly this is almost never the case. Actually P can give rise to a number of emergent integrated agents. Such agents can be identified by recursively repeating the above computation on P to yield a set of functional clusters $(PFC_p(t), FC_p^1(t), FC_p^2(t), ..., FC_p^m(t))$[7]. The members of such a set are all distinguishable in terms of their integration relative to their environment as long as their clustering index CI is significantly greater than 1. In the simple case however the $PFC_p(t)$ is the individuated agent and the rest of P is considered its environment E. We also assume that $PFC_p(t)$ is relatively slow-changing in time compared to the rate of information exchange between the agents that constitute it, but still it can present a rich repertoire of states due to both its interactions across the boundary and the interactions of agents inside its boundaries.

A functional cluster (Fig. 3a) is a set of agents which exhibit a synchronized activity for a limited duration. Functional clusters reveal integrated structural and functional properties of the network and are *snapshots* $(PFC_p(t = 1), PFC_p(t = 2), ...)$ of a continuous process of agents exchanging information with each other i.e. the dynamic core. The dynamic core's boundary drift can be observed as the temporal sequence of functional clusters (Fig. 3b). Remarkably, the dynamic core is defined in terms of interactions among agents, rather than merely in terms of their topological or functional relations (Edelman and Tononi 2000, p. 159).

[6] It is important to note that these are only simplified formulas that do not take into account the different sizes of subsets.

[7] See (Edelman and Tononi 2000, Chap. 14) for discussion of multiple functional clusters.

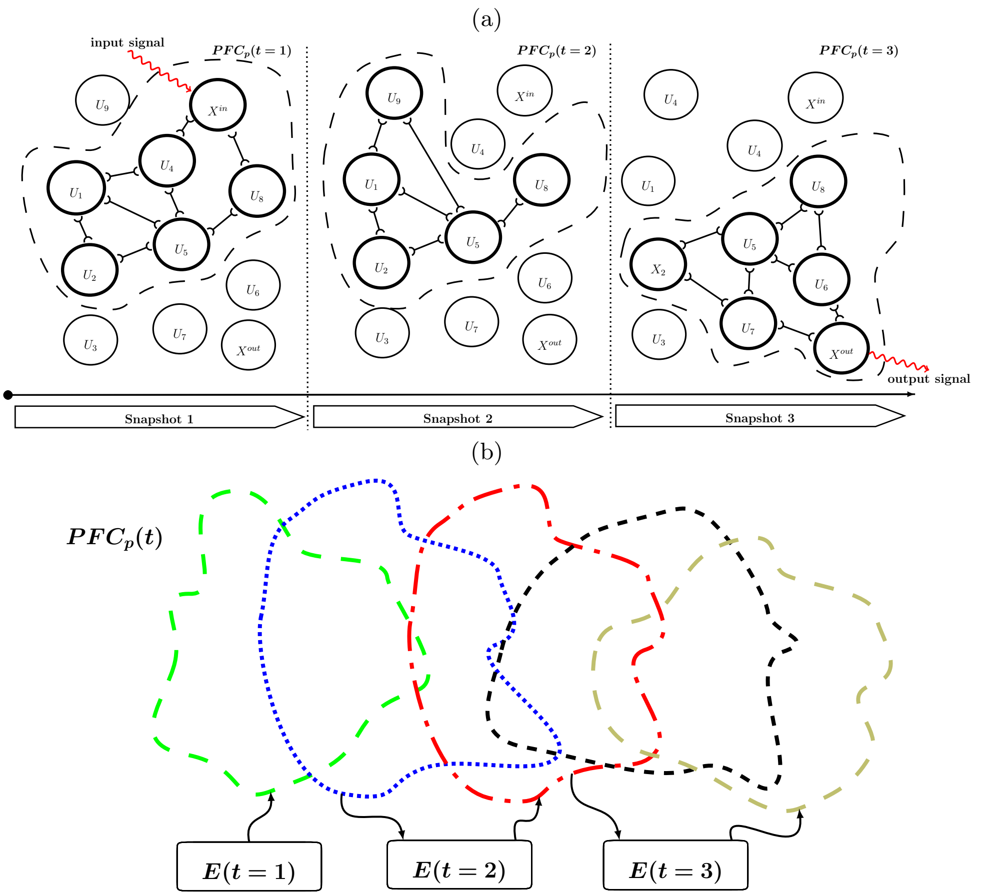

Fig. 3. Top figure (a): $PFC_p(t)$ developing along three consecutive snapshots in time. The boundary of the clusters moves from top right of the population to bottom right. The sequence of primary functional clusters depends on connectivity patterns, which results in the observed drift of the boundary. At the level of super-agent A's interaction with its environment, the given example of the drift of boundary illustrates a non-trivial response of $PFC_p(t=3)$ through X^{out} to a stimulus acquired by $PFC_p(t=1)$ through X^{in}. Bottom figure (b): the dynamic core interacting with its environment during five consecutive snapshots.

3.4 Operational complexity

A major characteristic of functional clusters pointed out by (Edelman and Tononi 2000, Chap. 11) is their complexity. Considering an agent as an integrated functional cluster, the complexity of the agent quantifies how differentiated are the agent's inner states, or, in other words, how many different states it can activate. Complexity is closely related to integration. If all the agents of a cluster had operated independently from each other, the cluster could have been said to have the highest complexity as its entropy would have been maximized. But then, with $CI \ll 1$ such a cluster is not a cluster at all but a collection of independent agents. Similarly, at the other extreme, a very high integration means very few possible states of the overall cluster, or, in other words, the states of individual agents of the cluster are mostly determined by global states. In such a case $H(PFC_p)$ approaches zero. The complexity of functional clusters therefore depends on the entropy of subsets within the cluster and the mutual information among them. Let X be a PFC of size M in the original population P. We assume that X is isolated from its environment[8] so its inner states are self produced. We divide X into two complementary subsets X_j^k and $X - X_j^k$ of respective sizes k and $M - k$. The index j, enumerates all possible subsets of size k out of X. The internal complexity of the cluster X can be given by:

$$C_{intrn}(X) = \sum_{k=1}^{M/2} < MI(X_j^k, X - X_j^k) > \tag{6}$$

where the mutual information is averaged on all subsets of size k. Clearly, subsets of very small size will contribute very little to $C_{intrn}(X)$, while subsets of sizes in the vicinity of $M/2$ will contribute the most complexity. Remarkably, C_{intrn} measure of complexity is based only on the extent to which subsets of the cluster affect each other and the statistical properties of the signals that agents within the cluster exchange. C_{intrn} therefore does not rely on an arbitrary measure of complexity imposed from outside the cluster.

To complete the picture, we consider two special subsets of the cluster X. X^{in} is the subset of the agents that receives signals from the environment across the boundary of the cluster (i.e. sensors), while X^{out} is the subset of agents that transmits signals to the environment across the boundary (i.e. actuators). X^{in} and X^{out} can of course overlap. Two additional useful quantified characteristics of a functional cluster is the degree to which it can be affected by its environment and the degree to which it can affect the environment. If the environment is defined as all the agents in P which do not belong to $X = PFC_p$ then we can define the environment as: $E = P - PFC_p$. While holding the states of all the agents in $X - X^{in}$ in constant state, we can compute the input complexity as:

$$C_{in}(X) = MI(X^{in}, E). \tag{7}$$

Similarly, the output complexity can be computed by holding $X - X^{out}$ in a constant state:

$$C_{out}(X) = MI(X^{out}, E). \tag{8}$$

Finally, the overall interactive complexity can be given by the mutual information of PFC_p and E when nothing is held constant:

$$C_{io} = MI(X, E). \tag{9}$$

These are of course simplified formulas that do not take into account the time dependencies of X, E, X^{in}, X^{out} and the variation in the dynamics of X^{in}, X^{out} that may arise from the different instantiations of the parts that are held constant in the computation. Nevertheless, even with these simplified formulations, the clustering index CI together with the various complexity measures $C_{intrn}, C_{in}, C_{out}$ and C_{io} inform us about the general characteristics of the emerging super-agent and its dynamics. C_{intrn}, for example, may indicate the memory capacity of the agent; the more integrated internal states are, the more 'experience' the agent can potentially draw from in its interactions.

4 Towards a generative model

In this section we outline the foundations of a generative model for cognitive development. By generative model we mean an implementable architecture that will

[8] The cluster can be initialized to some arbitrary initial condition.

demonstrate scalable cognitive development in terms that we described above, i.e. processes of self-organized differentiation, boundary formation and object relations. We identify two general mechanisms that are essential to our model, namely the transductive mechanism and the value modulating system.

The basic architecture of our cognitive development model is a heterogeneous population of agents that interact via links, thus forming a network. Information exchanges among agents result in the self-organization of clusters of agents that synchronize and coordinate their activities. Such self-organized clusters operate as distinct agents at a higher scale of organization. The most elementary formative processes in our model are the creation, reinforcement, suppression and destruction of links among agents. These formative processes are guided by the nature of exchanges among agents, e.g. Hebbian reinforcement rules in neural nets. All higher level formative mechanisms in our model are constituted from these elementary processes and their modulation.

4.1 Transduction

The mechanisms that are responsible for the formation of boundaries and the bringing forth of coordinated activities in a population of agents P arise primarily from the agents' intrinsic capabilities to affect and be affected by each other. The specific characteristics of the interactions, e.g. their frequency, their synchronization and coherence, have a critical influence on the way agents are connected. Such influence finds its expression in the reinforcement or suppression of connections among agents and consequently on how strongly they may actually affect each other. This is how *the activity of agents within P progressively determines the topological organization of the network of agents in P*. The structural organization, in turn, affects the overall function of the individual agents by selecting interactions. This recursive process of activity-determining structure and structure-determining activity is described in 2.4 as transduction[9] – the driving mechanism of individuation.

Individuation is described as taking place when two incompatible systems interact and achieve a certain degree of compatibility. In the generative model that we develop, agents in population P interact and mutually select other agents with whom they are compatible. The connections between compatible agents are reinforced while other connections tend to be suppressed. In the course of such recursive selective interactions, groups of compatible agents cluster into distinct compound organizations resulting in individuated super-agents. What needs to be further clarified is the criteria for compatibility utilized in the selective process and the actual mechanism of reflexive mutual selection taking place among agents.

Criteria for compatibility

Agents overcome their initial incompatibility by constraining each others' regimen of behaviors. In other words, there is a process of reflexive selection going on where every agent selects with which other agents in the population it can interact. We present here three understandings of the concept of compatibility from the simpler to the more complex. A concrete selective criterion of the adaptation of link strengths among agents is derived accordingly from each understanding:

[9] Deleuze uses the term *progressive determination* to describe the same process. See, Weinbaum (2015).

Synchronization – Agents that produce effects (become active) at the same time will tend to reinforce their connections.[10] The kind of compatibility that is selected by this criterion is temporal coincidence, which may indicate with some probability that the synchronized agents are causally affected by either the same event or by events that are causally connected, or events that are otherwise correlated. The formation of synchronized clusters of agents is the simplest form of individuation. Synchronized groups will tend to reinforce their synchronized behaviors and suppress their out-of-sync behaviors. Examples of individuation following this criterion can be found in neural networks. The Hebbian rule that neurons that fire together also wire together is one application of this criterion. A more complex application is provided by Edelman and Tononi (2000) who hypothesize that spontaneous synchronization among groups of neurons is the basis of consciousness.[11] From the perspective of our approach, both are examples of cognitive development at the scale of groups of neurons.

Coherence – Agents that produce effects (become active) in response to informative patterns (not necessarily synchronized) that represent the same category or type, or a group of mutually supporting logical propositions, or a group of associative patterns, will tend to reinforce their connections. The kind of compatibility that is selected by this criterion is much more abstract then synchronization and requires a context of operation. The agents connecting according to this criterion form coherent clusters. Clearly, in this general form, the coherence criterion is underspecified. Coherence will normally operate as a selective criterion only in populations of relatively complex agents where the information that agents exchange already signify lower level individuated objects. Such objects provide the context that further determines what coherence means. Thagard (2002) explains coherency as the joint property of propositions that tend to be selected together or rejected together when tested in the context of a certain domain or state of affairs. In our case, Thagard's understanding of coherence distills a second kind of compatibility, which we can generally describe as compatibility in signification or meaning.[12]

Coordination – Coordination is broadly defined as functional compatibility. In fact, synchronization and coherence can be described as special cases of coordination. Agents that interact, process information and produce effects that jointly realize a function or a goal are said to coordinate their operations, thus presenting functional compatibility. Connections among agents that support the coordinated activities will be reinforced while those that disturb the coordinated activities will be suppressed. The agents connecting according to this criterion will form coordinated clusters. As in coherence, coordination will operate as a selective criterion only in populations of relatively complex agents and where the information that agents exchange already signifies lower level individuated objects and their relations. Such objects provide the context that further determines the nature of the function or goal that are performed by the coordinated clusters. Autopoiesis Maturana and Varela (1980) is perhaps the most illustrative example of a self-organized coordination. Remarkably, autopoeisis is a function that operates in relation to the same cluster of agents that realizes it and therefore does not require an outside observer for its definition. Functional compatibility is not limited to this family of self-determined functions. Coordinated clusters may emerge in

[10] This does not exclude the formation of new links as well.

[11] See also Tononi et al. (1992) for a more detailed description.

[12] By incorporating various selective criteria, our approach to synthetic cognitive development suggests a unifying ground to both connectionist and symbolic models of intelligence. We see this as a promising prospect for further research.

response to signals mediated by the value system (see 4.2) that are external to the population of agents under consideration. Such signals guide selection by providing an external criterion of functional efficacy. In other words, the actual compatibility criterion of coordination may be either self-produced or external. The emergent agents, accordingly, may be self-coordinating or coordinated in relation to an external state of affairs. For an overview of coordination mechanisms see Heylighen (2013).

Though this short list of criteria seem to cover a very wide range of individuating processes it is not necessarily exhaustive. Novel understandings of compatibility may emerge in the course of an open-ended cognitive development process. However, we see no problem over incorporating such future developments into our model. On top of the criteria of compatibility we identify additional criteria under the general title *value modulating system*, or in short, value system. Values are not used explicitly in selection. Instead, they operate by modulating the plasticity of connections and by that quicken or slowdown the selective processes. The value system and its importance is further discussed in 4.2.

Reflexive mutual selection

In our generative model, individuated entities are the product of a recursive resolution of incompatibilities. This is a process of reciprocal selection where agents within a population repeatedly select communication links and interactions that increase compatibility according to the criteria outlined above. The reinforcement of compatible interactions and suppression of incompatible interactions progressively determine clusters of integrated agents within the population. Structural changes in the network of agents drive further selections and this transductive activity continues until the network achieves relative stability as individuated super-agents consolidate. At this elementary level, individuals emerge as products of an evolutionary process: the heterogeneity of agents in population P provides the variation and the various compatibility criteria provide the selective elements of the process. The retention of compatible clusters is inherent in the process since by definition mutual compatibility among agents is preferred and reinforced. Otherwise, no individuation and no cognitive development could have taken place.

Inspired by Edelman's theory of neuronal group selection (Edelman 1987; Edelman and Gally 2013; Tononi et al. 1992) the reflexive and recursive characteristics lie at the basis of our generative model. Our model extends neuronal group selection to general networks of agents. The selective criteria of compatibility that we derive from the theory of individuation extends the synchronization criterion in the case of neuronal groups. Reflexive mutual selection (termed "reentry" by Edelman) is a mechanism operating within a network of interacting agents. Consider two groups of agents A and B. Each group contains similar agents with some variety in their pattern of behavior. The groups are interconnected internally and across. Following a signal produced by some agent in group A, a subset of agents in group B will respond by producing signals too. This activation will spread both internally in B and across back to A (where some of the agents are already active too). A subset of agents in A will respond to the signals coming from B such that a chain reaction of signals will propagate back and forth between A and B. In some cases, after a few cycles of exchange, a signal, whether from an agent in B or A, will be received by the initiating agent and will cause it to produce a signal similar to the one that initiated the whole exchange. If this happens, a closed activation loop begins and the groups will enter a period of sustained mutual activation that will continue until it is disrupted by other

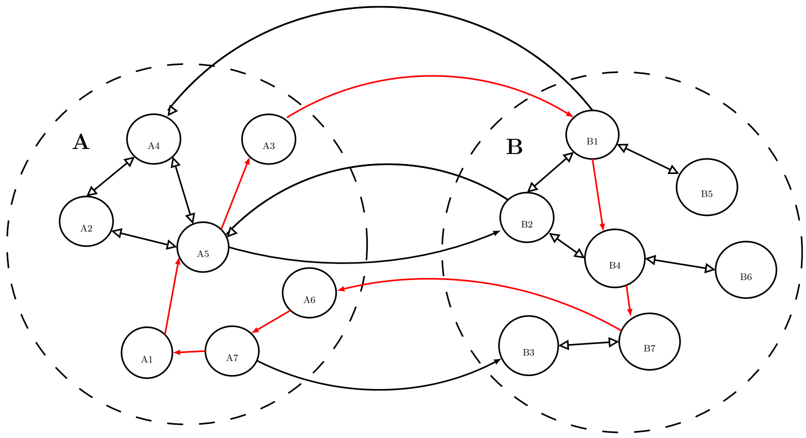

Fig. 4. Two connected groups A and B and the formation of sustained mutual activation. The signal propagation path of the sustained activation is indicated in red. Other paths such as A3-B1-B2-A5-A3 are topologically possible but are not selected because activation depends also on the informational content and timing.

signals.[13] Sustained activation patterns and sequences of interactions that arise in a similar manner within the population of agents are the products of what we call a reflexive mutual selection process.

4.2 Value modulating systems

In the context of the cognitive development of the human mind, value systems hold a potential to describe the mechanism of emotional influence on cognitive states, which is increasingly seen as a pivotal component of cognition. Pessoa (2009) points out: "Historically, emotion and cognition have been viewed as largely separate. In the past two decades, however, a growing body of work has pointed to the interdependence between the two". Fellous (2004, 1999) argues that neuromodulatory systems are the basis for emotions. In summary, emotional regulation is an important aspect of cognitive development (see 1.5). We therefore assign to value systems a critical regulatory role in our model.

In the enactive theory of cognition, Di Paolo et al. (2010) offer a definition for value as "the extent to which a situation affects the viability of a self-sustaining and precarious network of processes that generates an identity." Moreover, they emphasize a strong relation to the concept of sense-making: "value is simply an aspect of all sense-making, as sense-making is, at its root, the evaluation of the consequences of interaction for the conservation of an identity." Values are assigned to situations but they emerge from interactions as aspects of sense-making or, in other words, values emerge in the course of cognitive development. In the context of our research program we aim to examine how values and value systems develop. Particularly, the relations between built-in values and emergent values in the process of individuation at any given scale.

In the neuroscientific context (Friston et al. 1994, p. 2) take an evolutionary approach:

[13] The description here is simplified for the purpose of illustration. Sustained activation patterns may arise in many other, more complex ways.

> "The value of a global pattern of neuronal responses to a particular environmental situation (stimulus) is reflected in the capacity of that response pattern to increase the likelihood that it will recur in the same context. In this respect, value is analogous to 'adaptive fitness' in evolutionary selection, where the adaptive fitness of a phenotype is defined in terms of its propensity to be represented in subsequent generations. Thus, value plays a role in neuronal selection similar to that which adaptive fitness plays in evolutionary selection."

Friston et al. highlight the role of values as mediating evolutionary knowledge significant to fitness and already proven survival strategies. Cognitive development will accordingly be guided by values built-in by evolution. This approach assumes certain abstract principles (e.g. "food is good") that are independent of interaction and exist *a priori* to individuation. Di-Paolo et al. argue against this approach as a case of "[...] dealing with *pre-factum* evolutionary teleonomy, not with autonomy" and further explain that "[t]he point is not to argue that such norms do not exist across individuals [...], but rather that they should be searched for on the emergent level of autonomous interaction, not on the level of mechanism." We go a step further to argue that the emergent level mentioned by Di Paolo et al. extends beyond the individual (i.e. the autonomous entity) into the process of individuation.

But the gap between these approaches may be merely superficial. According to Friston et al., the structural and functional properties of the value systems needed for guiding neuronal selection should: (1) "be responsive to evolutionary or experientially salient cues" i.e. a wide context; (2) "broadcast their responses to wide areas of the brain and release substances that can modulate changes in synaptic strength"; (3) be "capable of a transient response to sustained input, inasmuch as it is changes in circumstances (environmental or phenotypic) that are important for successful adaptation". Value systems allow for the integration of broad contextual information in driving selective processes. Friston et al. (1994) notes however that a value is equivalent to an adaptive fitness in the evolutionary sense which guides, but *does not determine*, the further development of the organism.

In our model, we frame value systems in a broader framework of scalable individuation. We accommodate pre-determined norms in the dynamic construction of significance by individuals interacting in their environment. We argue that value modulating systems offer mechanisms of upward and downward causation which mediate among the various scales of the cognitive system (see Fig. 2). Values at a specific scale S operate as guiding signals originating from both the lower scale $S-1$ and the higher scale $S+1$. In both cases they modulate the operation of agents within the population P_s. Values that originate from lower scales can be viewed as built-in but they cannot be said to operate at the same domain of interactions characteristic to scale S. Every scale is a new layer of mediation whereby the possibilities to create meaning for signs become less constrained by the values of lower scales [14].

Synthetic cognitive development starts from explicit presuppositions and constraints which provide the basis for the generative process. These presuppositions define the primary repertoire of structures available for further cognitive development e.g. eyes, ears, pain receptors with their related neural structures in the case of mammals. Likewise, our notion of a value system starts from some presuppositions and constraints i.e. "innate values" that provide the initial structures. Value systems, then, undergo individuation along with the whole cognitive system. (Friston et al. 1994, p. 10) demonstrated that value systems allow for unsupervised acquisition of

[14] See (Di Paolo et al. 2010, p. 48–52) for a more detailed discussion that supports this approach.

new values in cases where they predict behaviors related to innate ones[15]. Following this, we hypothesize that similar mechanisms can be applied generally, meaning that novel sets of values are recursively acquired based on previously established ones. The specific characterization and implementation of such mechanisms is the subject of future research.

Presuppositions and constraints are necessary for modeling concrete instances of the cognitive development process. We nevertheless adhere to the perspective that the general cognitive development scheme based on the theory of individuation is not fundamentally constrained by any particular set of such presuppositions. Individuation as a formative process spans across scales beginning with natural evolution and going as far as open-ended intelligence expansion in humans, human organizations and machines.

5 Conclusion

We propose a novel approach to general intelligence based on the idea that intelligence arises in the course of a generalized process of cognitive development. We start by briefly exploring concepts from human cognitive development, enactive cognition, sense-making, and cognitive dissonance. We then sketch a scheme of cognitive development, conceptualizing it as an observable sequence of integration and disintegration processes progressively determining the cognitive complexity of an agent.

We further develop our scheme by following two parallel and complementary avenues. In the first, we present and briefly explore Simondon's theory of individuation. We argue that in the broadest sense, cognition is the bringing forth of a complex world of objects, entities and their relations through processes of boundary formation. Cognitive development can therefore be understood in terms of individuation – as a continuous formative process without *a priori* given capacities and competences. The concept of individuation provides a proper philosophical foundation to the emergence of intelligence through *synthetic* cognitive development, where intelligent cognitive behaviors are synthesized from significantly less intelligent ones. In the second avenue we develop a structural perspective of the framework by showing how the abstract process of individuation can bring forth progressively complex entities. Inspired by work in computational neuroscience, we propose information theoretic formalizations of self-organized boundary formation and the dynamic emergence of agents in an open-ended scalable scheme.

In the last part, we discuss topics necessary for further developing a concrete architecture for systems and environments capable of an open-ended emergent intelligent behavior. We explore an initial set of criteria needed for *reflexive mutual selection* – processes of spontaneous coordination of contingent interactions within a population of heterogeneous entities – which is a necessary driver of synthetic cognitive development. Finally, we discuss the role of value systems as mediators between adjacent scales of development.

The work presented in this article offers an alternative perspective to intelligence and is particularly relevant to general artificial intelligence research. It opens possibilities to profoundly alter our understanding of the relation between information systems, cognitive systems and the emergence of intelligent behavior.

[15] In "innate" we understand whatever is necessary for the viability of the individuals that are brought forth at a given scale. Value signals that originate form higher scales may however destabilize individuals whose continued existence is not significant anymore at higher scales of individuation.

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Chapter 12

Open-Ended Intelligence

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Open ended intelligence: the individuation of intelligent agents

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ABSTRACT

Artificial general intelligence is a field of research aiming to distil the principles of intelligence that operate independently of a specific problem domain and utilise these principles in order to synthesise systems capable of performing any intellectual task a human being is capable of and beyond. While "narrow" artificial intelligence which focuses on solving specific problems such as speech recognition, text comprehension, visual pattern recognition and robotic motion has shown impressive breakthroughs lately, understanding general intelligence remains elusive. We propose a paradigm shift from intelligence perceived as a competence of individual agents defined in relation to an a priori given problem domain or a goal, to intelligence perceived as a formative process of self-organisation. We call this process open-ended intelligence. Starting with a brief introduction of the current conceptual approach, we expose a number of serious limitations that are traced back to the ontological roots of the concept of intelligence. Open-ended intelligence is then developed as an abstraction of the process of human cognitive development, so its application can be extended to general agents and systems. We introduce and discuss three facets of the idea: the philosophical concept of individuation, sense-making and the individuation of general cognitive agents. We further show how open-ended intelligence can be framed in terms of a distributed, self-organising network of interacting elements and how such process is scalable. The framework highlights an important relation between coordination and intelligence and a new understanding of values.

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1. Introduction – intelligence and networks

We live in the age of networks: ecological networks, biological networks, digital networks, logistic networks, knowledge networks, social networks and so on. It is an age of plurality, of diversity and above all, of interconnectedness. The Internet, the most prominent actual exemplar of these concepts, is not only transforming the way we live and interact in the everyday, but furthermore has engendered a powerful image in our minds – the image of the network. This image has already a strong grasp over both the way we reason and our imagination. In that, it sets the horizons of possible invention (Hui & Halpin, 2013). Deploying networks as an explanatory platform for cognition and intelligent behaviour is an established practice in computational neuroscience (Edelman & Tononi, 2000; Tononi, 2008), general cognitive science (Bechtel & Abrahamsen, 2002) and other fields. The relations between the network concept and intelligence are many and strong. Primary of which is the fact that brains, the most advanced intelligent machines we know about as of today, are vast networks of interconnected neurones. The field of "narrow" artificial intelligence (AI) that focuses on goal-specific kinds of intelligence such as speech recognition, text comprehension, visual pattern recognition and robotic motion. has known quite a few impressive breakthroughs lately. The highly competent AI

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agents developed today rely heavily on vast networks of artificial neurones. Their construction is inspired by biological brains and their competences begin to rival those of humans in addressing specific problems.

The field of artificial general intelligence (AGI) is much more ambitious in comparison. It aims to distil the principles of intelligence that operate independently of a specific problem domain or a predefined context and utilise these principles to synthesise machines capable of performing any intellectual task a human being is capable of and eventually go beyond that. There is no doubt that the network concept holds powerful keys to understanding general intelligence and to the vision of building AGI agents. The goal of this paper is to examine, from a philosophical perspective, the conceptual foundations of intelligence and their emergence in the dynamics of distributed, disparate, interconnected structures.

The following section briefly introduces the current conceptual approach to general intelligence and criticises it. We expose a number of implicit hidden assumptions that the definition of AGI is based upon. These assumptions place *a priori* conceptual limits on how "general" general intelligence can be. Section 3 is a philosophical exploration of the ontological roots of intelligence and presents the theory of individuation, providing an alternative concept of intelligence as a process and not as a given competence. This novel approach overcomes the difficulties exposed in Section 2 and significantly extends the concept beyond the definition in Section 2.1. As the title of the paper suggests, the term *open-ended intelligence* will be used to describe intelligence as a process. In a nutshell, intelligence is the process of bringing forth a world of objects and their relations, or in other words, a continuous process of sense-making. Section 4 discusses how the process of individuation is applied to cognition as an ongoing sense-making activity. An important theoretical bridge is made between the concept of individuation and sense-making as an actual process of *cognitive development*. It is in the cognitive development of systems that open-ended intelligence is manifested. Here, by constructing a descriptive framework of the individuation of cognition, we study the various facets and implications of applying our approach and in what sense the formative individuating processes discussed are considered intelligent. We conclude with a list of open questions and issues for further research.

2. Conceptual problems with general intelligence

2.1. Definition of general intelligence

Intelligence is a difficult concept to define, especially in its general, context-independent sense. Many different context-bound definitions do exist, however, in diverse disciplines such as psychology, philosophy of mind, engineering, computer science, cognitive science and more. It is far from simple, if at all possible, to reach a common-ground definition that transcends the epistemological barriers between disciplines. Legg and Hutter (2007) have compiled the most comprehensive collection to date of definitions of intelligence. A shorter review of various representative examples of such definitions can be found in Legg (2008). Based on this broad review and their attempt to found a formal theoretical approach to general intelligence, Hutter and Legg have distilled the following definition:

> Intelligence measures an agent's ability to achieve goals in a wide range of environments. (Legg, 2008, p. 6)

This definition tries to capture the broadest possible consideration of goals and operating environments. Goertzel (2012) uses a slightly different version emphasising the pragmatic real-world "ability to achieve complex goals in complex environments", something that is somewhat lost in Hutter's AIXI all-encompassing design (Hutter, 2005). Still, from a foundational point of view, these two versions are in agreement. It would therefore be a good starting point to expose the problematic nature of such definition.

2.2. Criticism of the definition

Figure 1 depicts a scheme of the agent–environment model that is the basis for the above definition. The story that goes with the scheme is that the agent, based on a flow of observations it receives from

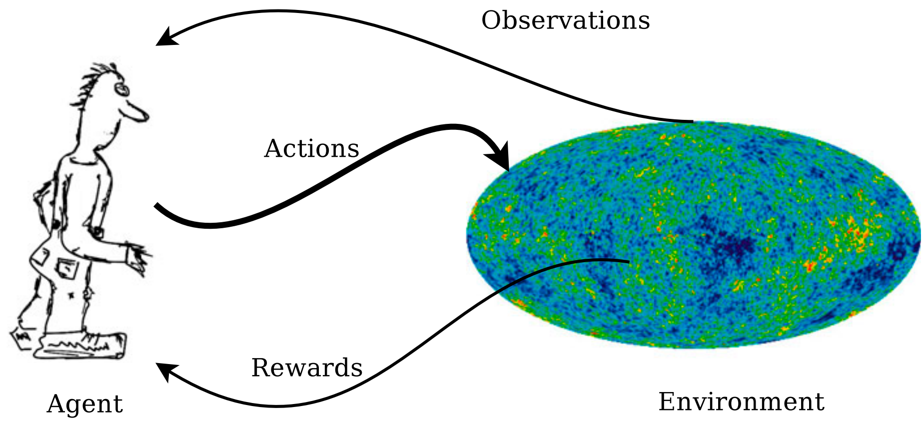

Figure 1. Agent–environment relations.

the environment, engages in a flow of actions made to achieve an optimised flow of rewards. The intelligence of the agent is a measure of its competence to match actions to observations such that it will achieve high rewards in a variety of diverse environments. With this definition, a few presumptions are already clearly apparent:

The agent–environment distinction – The first strong assumption is that the agent is clearly distinct from its environment. It has a well-defined contour across which it interacts with the environment. Additionally, the contour implicitly defines the kinds of interaction that can take place between the agent and the environment.

The environment – The status of the environment is problematic in two aspects: first, due to the hidden assumption about the *a priori* givenness of the environment and second, due to the assumption about its observer-independent status. In Hutter's AIXI model (Hutter, 2005), Solomonoff–Levin universal prior distribution (Legg, 2008; Solomonoff, 1964a, 1964b) is a minimal knowledge predictor of the environment's behaviour in the most general case. It incorporates both Epicurus' principle and the principle of Occam's razor (Legg, 2008, Chapter 2) and describes the agent's best guess given its initial ignorance regarding the environment. Using the universal prior as a basis, the agent can reliably induce the future distribution of behaviours of the environment as more data on its behaviour become available. But the subject matter of universal induction is only the agent's knowledge of the environment. The universal prior and the method of Bayesian induction assume an *a priori* given environment with an observer-independent status. Induction, therefore, only means the effective reduction of the observer's ignorance regarding the environment. Moreover, the actions of the agent can only affect the environment within its already given definitional constraints. The agent cannot *change* the environment – only discover its behaviour and respond. Agent–environment reflexivity, which is so apparent in actual systems, is either highly ambiguous or entirely left out.

Goal-driven reward – Clearly, the environment does not "give" rewards, as it is sometimes implied by considering it as an agent, only that certain states of the environment are more favourable than others relative to the agent's goals and in the context of its current internal state. For the definition of intelligence to be operative, it must therefore involve yet another presumption, namely that the agent possesses a clearly defined goal (or a set of goals) that maps values to both internal and environment states. In its actions, the agent attempts to move the environment from its current given state to the state that is most favourable in terms of rewards given the dynamic context of its internal state.

The agent's capacities – It is further implied that the agent is somehow structured by past interactions with the environment (knowledge) and has a computing capacity that affords the matching of actions to observations and the evaluation of rewards relative to its goals in the context of its state. This is of course a robust common sense assumption but as argued about the environment, presuming an agent endowed with *a priori* given general capacities, leaves a lot out of the equation. After all, intelligent agents do not spontaneously appear ready-made in some purely conceptual space. Some evolutionary process is necessarily involved and must not be overlooked.

All the presumptions listed here appeal strongly to common sense and frame the concept of intelligence in a reasonable and pragmatic manner. However, they also limit the generality of the concept in a few profound ways:

- Processes of differentiation and boundary formation that determine the agent–environment distinctions are excluded. Such processes that can be broadly categorised as processes of self-organisation can be gradual and possibly express intelligence of a kind that is not considered by the definition in Section 2.1.
- Processes that are not clearly defined *a priori* in terms of their goals and derived values are excluded. Defining a goal to be achieved is actually defining a problem to be solved. An intelligence that is constrained by an already given goal or a set of well-defined goals can hardly represent the ultimate generality of intelligence. In order to overcome this inherent partiality imposed by defined goals, suppose we could come up with a concept of a "universal goal" not dissimilar from the universal prior that generalises the environment. Clearly, this will result in an absurdity since every actual sequence of actions the agent might come up with in order to achieve a subset of this universal goal will be detrimental to another complementary subset. Defining a goal is a symmetry-breaking event that creates for the agent a *unique perspective* regarding its relations with the environment. Only on the basis of such a perspective can the agent possibly operate intelligently. But again, similar to the formation of agent–environment distinctions, the determination of a perspective that brings forth clear goals does not necessarily happen all at once. It might well take place in a gradual and unique process of determination which involves a kind of intelligence that the above definition is entirely overlooking. The intelligent agent characterised in Figure 1 is indeed a problem solver; still, it is argued that general intelligence never starts with solving a problem but much earlier – in the formation or identification of the problems to be solved.
- There is an unwarranted implicit asymmetry between the agent and the environment. While the agent is profoundly changeable by the environment, i.e. it accumulates knowledge through learning and adaptation, the environment is only changeable within the limits of its givenness (i.e. the actual yet unknown distribution of events it brings forth in the course of interacting). Such conceptualisation excludes environments that are populated by other intelligent agents. The reason is that such intelligent agent(s), being part of the environment, may have a distribution of responses that cannot be determined or inferred in advance, at least not without some prior knowledge of their goals. In short, the definition in Section 2.1 does not consider cases of reflexivity where, for example, two (or more) agents interact without any *a priori* knowledge of each others' goals and where such goals and their consequent behaviours emerge and consolidate in the course of interaction. If we consider that an agent's goals are set by an ongoing uniquely evolving perspective, it might be worthwhile considering an environment of co-evolving quasi-determined agents where the manifested intelligence profoundly departs from the presumptions made by the above definition.[1]

In the light of these points of critique, it is clear that the currently accepted definition of general intelligence covers only a well-characterised kind of intelligence but neglects the more profound and less easy to define process of the emergence of intelligence, or what we call *open-ended intelligence*. The difficulty lies of course in the *a priori* assumptions one is willing to give up. The less assumptions one commits to, the more difficult it is to make the concept concrete and formal. Wittgenstein famously said that whereof one cannot speak (clearly), thereof one must be silent. But then how can we explain babies learning to talk whereof initially nothing they say can be said to be clear? But still they do! Similarly, what is intelligence prior to anything intelligible?

3. The ontological roots of intelligence

To try to answer this question, we need to re-examine a few deeply rooted axioms and explore the less-charted conceptual grounds of how intelligence arises in the ontological sense. In other words, an attempt is made to reduce to the minimum the number of assumptions that constrain the concept. This is how we arrive at the concept of open-ended intelligence. As we will shortly show, it is a non-conventional concept; one that can never be spoken of clearly, but is not condemned to silence. The fluid and generative character of open-ended intelligence precedes and complements to the well-established concept of intelligence that we criticise. Without such a complementary approach, it seems that a truly general AI is bound to remain beyond the reach of understanding.

3.1. The ontological "chicken and egg" problem

Much of how one thinks about anything including intelligence is already encoded in one or more of the major philosophical theories that shape human thought. These thought systems usually make explicit some set of ontological axioms of what is given prior to any thought or idea, and from there they proceed to derive all that can be thought or made sense of. Let us see how it works in the case of the definition of intelligence. The definition begins with a realist empiricist view that can be summarised in two seemingly simple assumptions:

Realism – Posits that the whole of existence has an observer-independent status. In our case, it means that the environment exists independently of the agent interacting with it. Its structure and dynamics might be unknown to the agent but they nevertheless exist. Also, the agent's actions affect the environment only within the constraints of its independent givenness.

Empiricism – Following Hume, posits that all sense-making and consequently all knowledge and intelligent behaviour must derive from sense experience. In our case, it means that for intelligence to manifest, it is necessary for the agent to interact/observe with its environment because only via interactions/observations can it learn what is necessary to achieve its goals.[2]

But already here there is a difficulty reminiscent of the chicken and egg problem: what comes first, experience or the subject of experience? In Deleuze's discussion of the human image of thought (Deleuze, 1994, pp. 129–168), the subject of sense experience, in our case the agent, cannot be an *a priori* given as it is implied by the empiricist position. It must be somehow constituted in the course of sense-making. But this seems to be impossible because if we give up a subject *a priori* to experience itself, who or what is there to experience in the first place? This is indeed the major point of Kant's critique of Hume's empiricism. The Kantian position necessitates a transcendental subject in possession of transcendental categories (such as space and time) antecedent to what is given in experience in order to make sense of experience. But Kant's approach is not without its own difficulties. It must assume that certain mental categories precede any actual thought and any manifestation of intelligence. It is like saying that some form of primal intelligence must be inherent in the agent prior to any interaction. But what would possibly be the origin of such primal intelligence that transcends experience? Clearly, the idea of general intelligence expressed by the definition in Section 2.1 follows Kant in assuming that the agent possesses certain capacities and goals prior to any observation or action. Here, we face a second difficulty: how general is our agent's "general intelligence" if it must be constrained by *a priori* categories that shape its observations and goals that assign values to them? Our thinking about intelligence seems therefore to be constrained by abstract patterns that shape conventional thinking itself. These patterns, collectively termed by Deleuze "the image of thought", draw implicit limits on intelligence itself.

How can we overcome this difficulty and reach a conception of an open-ended intelligence? Following Deleuze (Deleuze, 1994; Weinbaum, 2014), we should neither try to figure how the objects of experience produce subjects (Hume's empiricism), nor how the subjects of experience produce their objects (Kant's transcendental categories). Instead, Deleuze proposes what he calls *transcendental empiricism*, a novel and seemingly paradoxical construction that affirms both Hume's and Kant's positions by redefining them. The position of transcendental empiricism starts with much fewer assumptions. It assumes neither subjects nor objects and instead of trying to figure how they might produce each other, it examines how both subjects and objects can be produced out of a field that initially does not assume either. Without delving more than necessary into the highly complex philosophical construction that is required here, we can start seeing where it leads in our case: giving up the *a priori* givens in our thinking, namely the agent, the environment, the distinction between them, the implied observations and actions that are made possible by such a distinction and finally the goal and its associated mapping of rewards. This might seem, at first sight, as if nothing is left to build upon and this clearly makes no sense. But here is exactly the point to stop and consider: If there is no sense, how is one to make sense out of a nonsense situation where no agents or objects can be identified to begin with? In other words, and here is the conceptual leap that needs to be taken, while the definition we started with in Section 2.1 is answering the question "what does it mean *to be* intelligent?", here the focus is on a prior question: "what does it mean *to become* intelligent?". Becoming intelligent is precisely this process of sense-making that precedes clear distinctions and goals and bring those forth. In order to see how is it possible at all, a novel and non-conventional set of concepts is required.

3.2. Individuals and individuation

One of the most profound characteristics of the conventional system of thought humans use to make sense with is its focus on individuals. This focus has its roots in Greek philosophy and particularly in the metaphysics of Aristotle, which describes a world made of individual beings with an identity that is given as a set of stable properties and qualities. Aristotle's principle of the excluded middle ensures that an individual cannot possess a certain property while simultaneously not possess it. Hence, the identity of individuals, according to the Aristotelian theory, is unambiguously defined.

Understanding the nature of individuals clarifies the general nature of definitions such as the one we use to define intelligence: definitions are made to delineate individuals. Most significantly, the focus on individuals also conditions the way one accounts for their genesis. To put it briefly, if individuals are the primary ontological elements of anything existing, the genesis of individuals is merely the manner by which one individual transitions into another one. Everything starts and ends with individuals, while the becoming of individuals – what happens in between – is secondary at best (Weinbaum, 2014). In order to make intelligence definable, we must make assumptions whose sole function is to comply with what the conventional system of thought dictates, namely positing already formed individuals on the basis of which we can safely continue to develop further individual concepts and theories.

Attempting to understand intelligence prior to such assumptions, we need a shift of perspective from individuals as the primary elements that occupy our investigation to *how they come into being* in the first place, in other words, to their *individuation*. Individuation is the formation or becoming of individuals. It is a primal formative activity, whereas boundaries and distinctions arise without assuming any individual(s) that precede(s) them. The nature of distinctions and boundaries is subtle; inasmuch as they separate subject from object, figure from background and one individual from another, they must also connect that which they separate. A boundary, therefore, is not only known by the separation it establishes but also by the interactions and relations it facilitates.

This shift of perspective constitutes an alternative system of thought. Gilbert Simondon, the father of the theory of individuation (Simondon, 2005) encourages us to understand the individual from the perspective of the process of individuation. For him, the individual is a metastable phase within a continuous process of transformation and is always impregnated with not yet actualised and not yet known potentialities of being:

> Individuation must therefore be thought of as a partial and relative resolution manifested in a system that contains latent potentials and harbors a certain incompatibility within itself, an incompatibility due at once to forces in tension as well as to the impossibility of interaction between terms of extremely disparate dimensions. (Simondon, 1992)

According to Simondon, an individual is not anymore the rigid well-defined Aristotelian element endowed with ultimately given properties, but rather a plastic entity, an ongoing becoming. The relatively stable state of individuals is punctuated by periods of transformation, whereas individuals may radically change or disintegrate. Every such period reconfigures the inner tensions active within the individual and the manner by which they will determine future stable phases and transformations.

3.3. The condition of individuation

Three descriptive terms stand out in Simondon's development of the concept of individuation: *metastability, intensity and incompatibility*. These are in fact overlapping facets of the field of individuation. Imagine, for example, a system of two (or more) human agents in disagreement having an argument. As long as they both continue to engage with each other and haven't reached an agreement, the situation of their engagement is metastable. There are unrealised potentials of change in their relations. One of them may suddenly understand the other better and change her mind. Also the opposite can happen: the differences between them can grow and reach a point of crisis. The system may move both towards or away from stability in a manner which is not entirely predictable and depends on numerous factors. But as long as the argument continues, as long as the system is metastable, there is a motion of change. Individuation in this sense is reminiscent of the concept of self-organisation in dynamic systems both in its reference to metastability and in the emergence of structure in a process of relaxing a system of tensions/potentials. But while self-organisation commonly describes the convergence of trajectories towards attractors within an already configured state-space, individuation does not assume such an *a priori* configuration. Simondon's notion of metastability is not confined to describing trajectories of movement among local minima within an already given landscape of potentials; metastability also involves possible transformations of the landscape itself (e.g. the number of the involved variables and the relations between them).

Individuation takes place as long as the system has not reached a final stability/relaxation and exhausted all its potential for change. But in fact, final stability is merely an idealisation because it requires a closed system that either does not interact with its environment, or is not distinct from its environment (i.e. in thermodynamic equilibrium with its environment). Open systems like living organisms or whole ecosystems maintain a far-from-equilibrium state (Prigogine & Stengers, 1984), and are in a motion of continuous individuation never reaching permanent stability.

The motion of individuation is driven by what can be called intensive differences, or in short, intensities. By intensity, we mean here a general term for energetic differences that drive structural and state changes in a system (see, DeLanda, 2013; Weinbaum, 2014, Chapter 2). In the example above, the driving intensities are the interlocutors' desire to each hold to her own convictions and persuade the other to change his. This desire is a force that drives and animates the interaction. Intensities can either dissipate as the system changes, or they can also become too strong for the system to contain and thus bring about the disintegration of the system. Applied to our example, in both cases, the activity of arguing will tend to cease. If the interlocutors manage to agree on a certain point, intensities are relaxed and their relations gain additional consensual structure (understanding). But if, on the contrary, they discover that their differences are even deeper than they initially thought, intensities increase and may find their expression in the manner the argument is conducted, e.g. it becomes heated, or even escalates to physical violence, which is not anymore an argument. Generally, intensities are correlated to the measure of metastability and level of structural changes taking place in the system. Low intensities are associated with relatively more stable dynamics, while high intensities are associated with volatile dynamics and swift structural changes.

Last but not least is the third term – incompatibility. Only situations of incompatibility bring forth intensities that drive processes of individuation. Incompatibility arises from what we may call the problematic – the situation where interacting elements of a system pose problems to each other that require resolution. The engagement of predator and prey is an exemplar of a problematic situation of incompatibility. In the argument example above, thinking differently about a situation that requires from the agents a joint coordinated action is an example of a problematic situation. The differences in perspective between the agents must be resolved at least to a degree that allows the necessary joint action. Disparity is an extreme case of the problematic where the semantics of the signs exchanged between agents/elements in a system is not established or ambiguous. The agents lack a common ground of basic coordination/understanding to even facilitate their engagement (e.g. they do not speak the same language). In such cases, individuation must also mean the emergence of a coordinated exchange of signals (is this strong hug a gesture of friendship or a covert threat?). It is important to note that the individuation of systems in general always starts from a situation of disparity. It takes place in the course of gradually establishing a coordinated exchange of signals among gradually differentiating elements that together (distinct signals and elements) bring forth a system. In other words, both elements and the relations among them are simultaneously individuated. Furthermore, individuation never brings forth an individual in a vacuum but rather an individual-milieu dyad. This dyad contains both a system of distinctions and a system of relations. The individual and its milieu reciprocally determine each other as they develop as a system greater than the individual (Simondon, 2009).

3.4. Transduction – the mechanism of individuation

What happens in individuation? In the example of arguing persons, the involved agents are continuously affecting and being affected by each other. In the course of their interactions, some (but not necessarily all) of the disparities and problems are resolved and result in a new consensual structure that they will support together in the future. This is how the system is individuated and gains an identity of its own based on the established coherency achieved between the agents. It is important to note that at any instance, the system constituted of the agents and their relations includes both consensual positions that form its individuated aspect (because they can be identified and defined for the entire system), and elements of unresolved incompatibility that may drive future engagements leading either to extended coherency or the destabilisation of the already established consensus. What may seem to an external observer as a stable and coherent system, always harbours internal intensities and instabilities that threaten to radically change it or even break it apart. These latter elements, termed *preindividual*, are intrinsic to all individuals and are the inner intensities that drive future individuation.

The outcome of the interaction between two or more incompatible agents is hardly predictable since it is not guided by *a priori* individuated overarching principles or mechanisms. In other words, the outcomes of such interactions can neither be deduced from an already individuated set-up, nor can they be induced from a generalised model based on previous similar instances because incompatibilities are inherently singular and unrepeatable. The methods of deduction and induction therefore cannot be applied to individuation (Simondon, 2009, p. 12). Prior to, and in the course of the actual interaction, the outcome is said to be *determinable but not yet determined*. Determination necessitates the actual localised and contextualised interaction where the participating elements reciprocally determine behavioural and structural aspects of each other. This kind of interactions constitutes the mechanism by which individuation takes place as a sequence of *progressive determinations* and is called in short *transduction*. Transduction is an abstract mechanism that may receive its specific actual description per context or operational domain. It can be physical, biological, cognitive, social or other according to the agents and interactions involved.

The most important aspect revealed in transduction is the progressive co-determination of structure and behaviour. Transduction can be seen as a chain of operations O_i on structures S_j: $S_1 \rightarrow O_1 \rightarrow S_2 \rightarrow O_2 \rightarrow S_3 \rightarrow \ldots$ (Combes & LaMarre, 2013, pp. 14–15). Every operation is a conversion of one structure into another, while every structure mediates between one operation and another. Each structure in the chain constrains the operations that can immediately follow. Each operation, in its turn, can transform the previous structure into a limited number of new structures. Every intermediate structure is a partial resolution of incompatibility, but it is driven away from its relative stability as long as the remaining unresolved tensions are not exhausted. Initially, the series of operations or structures can be quite random. As the transductive process progresses, certain structures and operations may become more frequent than others or even repetitive. As the sets of structures and operations become mutually bounded, even temporarily, an individuated entity arises which may either further consolidate or eventually disintegrate (this is further discussed in Section 4.3). A more concrete example of a transductive process is the propagation of a computation in self-transforming programs: executed code and the data are analogous to operation and structure. However, the program code itself is also accessible as data that is progressively modified to produce (in principle) inexhaustible variety and innovation. Code redefines the data and data further redefine the code in a chain of operations. The analogy helps to understand how operation and structure are reciprocally determining expressions of the transductive process.

3.5. Assemblages – from individuation to individuals

Understanding individuation is understanding how individuals are constructed from sets or populations of disparate and heterogeneous elements. The monolithic stable character of individuals is given up and instead we see metastable and often troublesome constructions that can be defined and identified but only as provisional stations in an incessant process of transformation. These constructions are called *assemblages* – a concept developed by Deleuze and Guattari (1987) and further extended by De Landa (2006).[3] Assemblages are networks of interacting heterogeneous individuals where each individual is an assemblage too (for elaboration on the stratification of assemblages, see Section 4.2). Assemblages carry with them an intrinsic though metastable individuality; an individuality that does not depend on an external observer but only on the relations that have been stabilised among their disparate elements.

When we observe a system of any kind, be it a physical object, an organism, a technological artefact or a social system, as observers we form with the object of observation a new assemblage. Both observer and observed and the relations between them undergo a transductive process of individuation where disparities are resolved and coherent relations are established. These come to constitute knowledge – an individuated knowledge. The individuation of knowledge is the process already mentioned in Section 3.1 where both the subject and object of knowledge reciprocally determine each other without one having a privileged ontological status over the other.

Replacing the individual with individuation as the primary ontological element exposes a hierarchy of creative processes across many scales. When we examine an individual, we need to identify which are the elements relevant to its individuation. For example, to say that a living organism is made of atoms does not expose anything interesting about the organism's individuation. An individual organism individuates from a lump of identical cells originating from a single cell in a developmental context (egg, womb or a cell membrane in case of unicellular organisms). An individual species individuates in an evolutionary context (ecology). In the case of social animals, further individuation takes place in a social context. Every such context can be given as a population of heterogeneous and disparate elements from which individuals and their milieu co-emerge.

Individuals as assemblages come to mean that the assembled elements can be said to be characterised by (a) identifying properties that define them as the individuals that they are (and subject therefore to their own individuation) and (b) capacities to interact – to affect and be affected by other elements (De Landa, 2006, Chapter 1). While every element has a more or less fixed and independent set of properties, the set of its interactive capacities is open and inexhaustible because it depends on the actual relations that each element forms with other elements. Since there is no limit to the number and kind of relations, the set of capacities to interact is open-ended and non-deterministic. What becomes determined in transduction are the actual capacities manifested in the interactions of the various elements involved in the process. This is why the actual interaction is necessary for the determination and why the resulting relations cannot be predicted *a priori*. Once disparate elements come into (partially) coordinated relations, they give rise to an assemblage – a new individual with more or less stable properties and capacities.[4] Critical to the concept of assemblage is the semi-autonomous status of their constituting elements and their contingent relations. Even in a radical example such as an organism or even a living cell where the integration between the constituting elements seems to be very tight, the relations between organs are not a result of a logical necessity but rather contingently obligatory (De Landa, 2006, p. 12). This is why tissues can spontaneously become cancerous and individual organs can be taken out and replaced by artificial organs such as bionic limbs, artificial kidneys, hearts, joints and retinas to form cyborgian assemblages.

To summarise, transduction and assemblage are both aspects of individuation. While transduction describes the dynamical aspect, assemblages frame the structural aspect. Together they form a conceptual framework that allows the investigation of the individuation of intelligent agents free of the assumptions reviewed in Section 2.2. An interesting reflection arises from the distinction between properties and capacities: since the conventional approach to general intelligence conceives it as a definable property of an agent or a system, there is a certain inherent finiteness in its very conception. In contrast, the complementary approach to general intelligence proposed here conceives general intelligence as a capacity. As such, it is open-ended and involves indefinite and *a priori* unknown factors depending on contingent interactions. In other words, a creative aspect that goes beyond goal-oriented, utility-optimising activity is intrinsic to the open-ended intelligence that manifests itself in individuation.

4. Intelligence in the individuation of cognition

From the perspective developed here, it is interesting to regard every individual – the product of individuation – as a solution to a problem whose formulation is not initially given and can only be implied from the solution (i.e. the individual). As was already mentioned, individuation is a resolution of a problematic situation by means of progressive determination. What is meant by "a problematic situation" is a state of affairs that is unstable, non-organised, whose elements lack definite boundaries and coordinated interactions and therefore does not give itself to any systematic description.

In contrast to the definition given in Section 2.1, where the starting point is a well-formed problem to which a solution is being sought, in individuation the endpoint, i.e. the individual, is a well-formed solution to a "problem" that is initially unformed and therefore can only be implied "backwards" from the solution. Following this line of thought, we do not depart in any radical sense from the understanding of intelligence as a general capacity of solving problems. Our thesis is that the formative processes that bring forth individuals as "solutions" to problems that are initially unformed are manifesting an open-ended kind of intelligence which is qualitatively different and complementary to the one defined in Section 2.1.

Furthermore, the designator "general" in general intelligence must relate to a process where a problematic situation is initially unformed (i.e. determinable but not determined) but involves intensities that mobilise the bringing forth of individuals as "solutions". The most significant example that comes to mind here is the process of natural evolution. Every living organism manifests a set of behaviours that realise highly optimised solutions to problems that become apparent only while observing the interactions of the organism in its environment. Organisms therefore are undeniably intelligent. But what about the evolutionary formative processes that give rise to the outstanding "solutions" that living organisms are? We argue that they are intelligent precisely in the complementary sense we propose here and in this profound sense deserve, more than anything else, the designation of general intelligence.

To this point, the theory of individuation has a very broad scope as it relates to individuals in general and not necessarily to what is conventionally considered intelligent systems or intelligent agents. From a philosophical perspective, general systems whether natural like galaxies, stars, rivers, chemical compounds and weather systems, or artificial such as tools, machines, buildings, wars and mathematical computations are individuals in the course of individuation that possesses an intrinsic and identifiable (though in most cases limited) manifestation of intelligence. Our interest, however, is not in the limited and already consolidated manifestations of intelligence but in those manifestations which are, at least in principle, open-ended, i.e. in the process of becoming intelligent. In the following section, we develop the idea that the individuation of cognitive systems, where cognition is understood in its broadest possible sense, is by definition a process manifesting open-ended intelligence.

4.1. Cognition as sense-making

The phenomenon of cognition is definitely complex, multifaceted and gives itself to quite a few diverse definitions. Still, in a somewhat naive approach, the activity of cognition is naturally associated with certain situations when there is an agent operating in its environment, and whose operation can be described as an ongoing problem-solving activity. In other words, the roots of cognition are always a problematic situation, an incompatibility, full of tensions, that exists between the agent and its environment and that needs resolution somehow. This also lends the impression that a cognitive agent is always involved in some purposeful activity, that is, resolving an immediate (or a forethought) problem. This is also the straightforward manner by which cognition is associated with intelligence.

Here, we turn full circle to the beginning of our inquiry: How is it that this set-up of agents, environments and their dynamic problematic relations emerge in the first place? Even while writing (or reading) these words, we make use of sensible objects that are already, at least partially, formed. Perhaps they are vague and require further determination to become clearer; some may change the meaning (sense) in which they are understood; others may just emerge in the flow of thought or disappear; and yet others may merge or diverge. Crossing this, often unseen, boundary between the unknown and the known, the unformed and the formed is what we may call *sense-making*. Sense-making is the bringing forth of a world of distinctions, objects and entities and the relations among them. Even primary distinctions such as "objective-subjective" or "physical-mental" are part of sense-making.

A relatively new appearance on the stage of cognitive science, the so-called *enactive cognition* approach, regards sense-making as the primary activity of cognition. The term "enactive", synonymous with "actively bringing forth", makes its first appearance in the context of cognition in the book "The embodied Mind" (Varela, Thompson, & Rosch, 1992) and has been since then the subject of many developments and debates (De Jaegher & Di Paolo, 2007; Di Paolo, 2006; Stewart, Gapenne, & Di Paolo, 2010; Thompson, 2007). The enactive theory of cognition incorporates the idea of individuation rather naturally as it asserts cognition to be an ongoing formative process, sensible and meaningful (value related), taking place in the co-determining interactions of agent and environment (Di Paolo, Rohde, & De Jaegher, 2010). Still, being based on the earlier works of Maturana and Varela on autopoiesis and the biological basis of cognition (Maturana & Varela, 1980, 1987), the theory asserts the necessity of an autonomous and relatively stable identity to cognition:

> A guiding idea of the enactive approach is that any adequate account of how the body can either be or instantiate a cognitive system must take account of this fact that the body is self-individuating. This point brings us to the principal concept that differentiates enactivism from other embodied approaches to the mind – the concept of autonomy. (Di Paolo & Thompson, 2014)

And in Di Paolo et al. (2010), the necessity is made specific to sense-making:

> [. . .] By saying that a system is self-constituted, we mean that its dynamics generate and sustain an identity. An identity is generated whenever a precarious network of dynamical processes becomes operationally closed. [. . .] Already implied in the notion of interactive autonomy is the realization that organisms cast a web of significance on their world. [. . .] This establishes a perspective on the world with its own normativity[.] [. . .] Exchanges with the world are thus inherently significant for the agent, and this is the definitional property of a cognitive system: the creation and appreciation of meaning or sense-making, in short. [. . .] [S]ense-making is, at its root, the evaluation of the consequences of interaction for the conservation of an identity. (Di Paolo et al., 2010, pp. 38–39,45)

In contrast, we argue that the broader understanding of sense-making as the individuation of cognition itself precedes the existence of already individuated autonomous identities and is actually a necessary condition to their becoming. Only that at this preindividuated stage, there is still no one for whom sense is being made. It is only a habit of thought to assume the pre-existence of the sense-making agent to the sensible (see Section 3.1). Di Paolo et al. are nevertheless aware of the metastability involved in the processes that constitute cognition by mentioning *precarious networks of dynamic processes becoming operationally closed*, but they do miss the deeper meaning of becoming as a process and therefore treat closure as an ideal point that delineates the existence of the individual in time, and that only from such a point and on sense-making is made possible. This is an important point because it frees intelligence from being conceptually subjugated to the persistence of a preexisting identity. The sensible, we argue, precedes the individual and facilitates its becoming but in itself is not necessarily biased towards the conservation of any identity. In sense-making, both integration and disintegration play a significant role.

To summarise, the manifestation of open-ended intelligence in cognition is the bringing forth of a complex world via the activity of sense-making. The concept of sense-making captures two distinct meanings: the first is synonymous with cognition as a concrete capacity, the second, with the individuation of cognition as intrinsic to cognition itself. The latter meaning of sense-making is the one corresponding to the acquisition and expansion of concrete cognitive capacities (i.e. intelligence expansion) and it also generalises the concept of *cognitive development* beyond its psychological context (Piaget, 2013).

4.2. A descriptive model of the individuation of cognition

To describe the process of individuation of cognition in more concrete terms, we consider a heterogeneous and diverse population P of individual elements each with its defining properties and capacities to affect and be affected that depend on contingent interactions with other elements of the population. By "heterogeneous", we mean a population of individuals with different sets of properties, whereas by "diverse", we mean that there is variability in the expressions of at least some of the properties. An obvious example would be a population of organisms within an ecology: the population is heterogeneous because there are many species and it is diverse because specific properties have variability in expression within a species and across species. The formation of new individuals within heterogeneous and diverse populations of interacting elements is at the core of our model. It highlights the distributed nature of individuation and the kind of intelligence that is thus brought forth.

As already described in Section 3.5, individuals are actually individuated assemblages. For reasons that will become clear shortly, we assign the population we start with to a stratum P. Stratum P implies two additional populations (i.e. strata) with which it holds hierarchical relations (Figure 2):

(1) Lower in the hierarchy is the population of all the individuals that participate as components in assemblages that constitute the individuals in stratum P. We mark it P_{sub} for being the substratum of P.
(2) Higher in the hierarchy is the population of all the individuals whose assemblages are constituted from individuals in stratum P. We mark it P_{sup} for being a superstratum of P.

This hierarchical relation of assemblages unfolds recursively both upwards and downwards where each level is the substratum of the level above it. Lower levels are populated by successively simpler

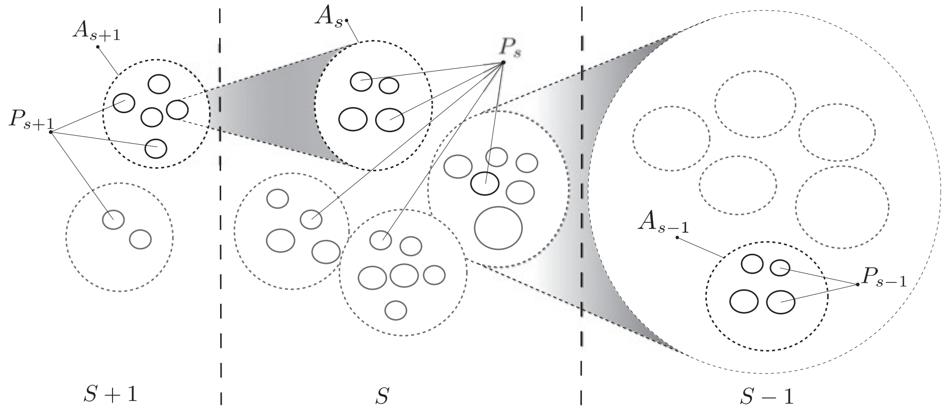

Figure 2. Relationship between strata in the model: S consists of P, $S+1$ consisting of P_{sup} is the superstratum and $S-1$ consisting of P_{sup} is the substratum. P_s denotes the population of agents at stratum S. Solid circles denote the individual agents at any stratum. Dashed lined circles denote assemblages at any stratum, e.g. – A_s at the centre of the figure denotes a super-agent that emerges from the interactions of agents in S. Assemblages at stratum S are the individuated agents of stratum $S+1$.

elements and higher levels are populated by successively more complex elements, so different levels in this hierarchy are of a different scale of complexity.[5]

This simple scheme allows us to describe the transductive mechanism operating at stratum P from two distinct perspectives: (a) P_{sub} provides the "raw material" perspective for the processes in P in terms of already individuated elements that are given[6] and (b) P_{sup} provides the "product" perspective for the processes in P in terms of the individual objects that are individuated in P. Stratum P, therefore, is a field of individuation where individual elements from P_{sub} get assembled by the actual interactions taking place in P to produce the higher level individual elements in P_{sup}. The assemblages that emerge in P are products of a sense-making process taking place in P and therefore can be said to become *sensible* in P.

The individuals operating at each strata can be broadly defined as agents considering their capacities to affect and be affected. Specifically, in our model, the individuals described at each stratum are cognitive agents, whereas their capacities grow in complexity across strata from the most primitive distinctions and actions at lower strata to highly complex sense-making activities at the higher strata. Even so, at this level of description, we do not have to assume agents with intrinsic values or goals that require a certain level of autonomy as discussed above in Section 4.1. We only need to require that minimally some of the capacities to affect are also within what is possibly affected by interactions with other agents. In other words, the agents' behaviours are, at least to a minimal extent, affected by their interactions. This requirement comes to ensure that some individuation can take place. Clearly, if the agents' capacities to affect had been entirely independent from their capacities to be affected (and vice versa), they could not change one in relation to the other and therefore no transductive process would have been possible in such case.

In summary, we introduce two distinct kinds of relation among agents; horizontal and vertical. Horizontal relations are internal to each stratum and describe the actual interactions that bring forth individuation. The vertical relations are across adjacent strata and describe hierarchies of individual objects differing in complexity and their upward and downward effects. While conceptually the individuation of elements at any stratum follows the same transductive mechanism, the actual mechanisms are context-dependent and can be vastly different; the resolution of disparities between neurones, for example, is nothing like the resolution of disparities between goals, needs and constraints in the mind of a single human individual, and is nothing like the resolution of disparities between humans or between social organisations constituted of humans and their artefacts. Nevertheless, the guiding principle of individuation and its self-similarity across strata introduces a general model of cognition that is scalable and open-ended.

There is no end, in principle, to the possible expansion of intelligence via the emergence of new strata of individuation. Whenever a population of cognitive functions/objects emerges with enough diversity and heterogeneity to become the substratum of novel individuations, a higher stratum of cognition can potentially emerge. The emergence of a population of a new kind of individual (e.g. new species in macroevolution, a new kind of explanations allowed by a novel theory, mobile devices, applications of deep learning algorithms, etc.) can be thought of as a phase transition event in sense-making where certain kinds of assemblage that were rarely present before, if at all, suddenly become ubiquitous, diverse and heterogeneous. When such an event takes place, it can often be associated with a new method or set of methods of resolving problematic situations and coordinating elements into wholes that could not be integrated before. Phase transitions in sense-making are possibly the underlying driving principle behind *metasystem-transitions* – a theory of the evolution of complexity in general systems (Heylighen, 2000; Turchin, 1995; Turchin & Frentz, 1977).

4.3. Phases of sense-making

Actual sense-making is a continuous process of integration and disintegration of discrete individuals taking place in a network of agents and their interactions. In the context of cognition, sense-making is synonymous with individuation. It is important to note that in our general approach to cognition, there is no *a priori* subject who "makes sense". Both subjects and objects, agents and their environments co-emerge in the course of sense-making. For clarity of description, a few phases can be identified in the process, given that this deconstruction into phases is largely didactic.

4.3.1. Preindividual boundary formation

The spontaneous emergence of an agent–environment dyad from a random network of interactions can be thought of as the formation of a boundary that distinguishes a subset of agents in population *P* from all the rest. Boundary formation corresponds to self-organisation in the broadest sense. Once there is a boundary, interactions across the boundary also gain a distinctive significance in the sense that now the set of all possible interactions can be further categorised in relation to the boundary, i.e. those interactions across the boundary and all the rest. Therefore, the formation of a boundary is equivalent to symmetry breaking over the population of agents and their interactions.

Initially, boundaries that arise are not fixated and possess no tendency to persist. Nevertheless, boundaries can persist, for a while, even without actively resisting change if they are not perturbed. How is the spontaneous formation of boundaries possible? Without specifying the exact nature of the interactions that are responsible for that, we can assume that in a network of interacting agents, there will exist a non-uniform distribution of interactions over the population. There will be subsets of agents that spontaneously affect each other more strongly or frequently than they are affected by the rest of the agents of the population. Observing such a network for long enough and drawing a map of the density of interactions, one would, in most cases, find regions of higher density of affective interactions (i.e. interactions that change the state of the participating agents) compared to their surroundings. This non-uniformity of affective interactions can be further quantified in information theoretic terms following the concept of *information integration* developed by Guilio Tononi (Edelman & Tononi, 2000; Tononi, 2004, 2008) in the context of computational neuroscience. A simplified mathematical development of the concept can be found in Appendix 1.

The information integration of a set of interacting agents is a relative measure of how strongly their states have become mutually correlated in comparison to their correlation with the rest of the environment. In our case, information integration is used as a clustering criterion that singles out from the population *P* subsets of agents that are significantly more integrated in the sense of affecting each others' states. The information integration of groups of agents requires no *a priori* assumptions regarding their dynamics. In other words, informational integrated clusters can contingently arise and spontaneously persist for a while. But this contingent arising is sufficient to initiate a process of individuation eventually bringing forth order out of disorder.

Information integration is a necessary indication to boundary formation but is not a sufficient condition to individuation. What seems to be necessary for boundaries to consolidate and persist is an additional element of regularity or repetition in the interactions. This element is perhaps best reflected in Deleuze's introduction to the English translation of his book on Hume's empiricism:

> We start with atomic parts, but these atomic parts have transitions, passages, "tendencies", which circulate from one to another. These tendencies give rise to habits. Isn't this the answer to the question "what are we?" We are habits, nothing but habits[.] (Deleuze, 1991, p. x)

At this very primal phase of boundary formation, we are interested in what would be minimally sufficient to make contingent boundaries more distinct and persistent and by that drive individuation further. In our model, interactions take place with some initial probability distribution, and this leads to an initial distribution of information integration. The missing element can be understood as a kind of a cybernetic mechanism that reinforces differences in information integration, that is, integrated clusters of agents will tend to increase the probability of future interactions (and subsequent correlations in state) within the cluster in proportion to the present degree of integration. In other words, similar to Hebbian learning (Hebb, 1968), agents that are already correlated to some extent will tend to increase their correlating interactions, whereas the frequency of other interactions will relatively decrease.

The reinforcement of the frequency of interactions is a general and simple conceptualisation of the "habit forming" tendency. With such a tendency, not only do boundaries form spontaneously, but they will tend to become more distinct once formed. Various specific reinforcement mechanisms are possible; the reinforcement can depend (positively or negatively) on the kind of interactions and the content of the information being exchanged between agents, but at the moment, we are only interested in the conceptual framing of a model of individuation with minimal assumptions. With this additional cybernetic element, the activity taking place within the network at any moment T influences the future structure of the network at times $t > T$ as it makes certain links stronger than others. Also, the interacting agents gradually co-determine their future interactions. These two effects are the definitional marks of a transductive process going on, as we have seen in Section 3.4.

4.3.2. Closures, autonomy and identity

The phase of sense-making that corresponds to already formed individuals is characterised by the emergence of special types of dynamic structures called *operational closures*. Operational closure is a central concept in the enactive approach to cognition and is the basis of the so-called self-constituted or autonomous systems with identity that were already mentioned in Section 4.1:

> An identity is generated whenever a precarious network of dynamical processes becomes operationally closed. A system is operationally closed if, for any given process P that forms part of the system (1) we can find among its enabling conditions other processes that make up the system, and (2) we can find other processes in the system that depend on P. This means that at some level of description, the conditions that sustain any given process in such a network always include those conditions provided by the operation of the other processes in the network, and that the result of their global activity is an identifiable unity in the same domain or level of description (it does not, of course, mean that the system is isolated from interactions with the environment). Autonomy as operational closure is intended to describe self-generated identities at many possible levels. (Di Paolo et al., 2010, p. 38).

Implicit in this definition are a few important points. First, certain capacities of the agents (processes) involved gain significance as they become enabling conditions to the operation of other agents. The generality of affecting and being affected is further determined here, because it specifies *how* certain agents affect or are affected by others. Conceptually, this implies a certain level of compatibility among the agents involved and therefore it means that for operational closures to arise, certain compatibilities among the participating agents must be present. These compatibilities provide a common descriptive ground that allows the various heterogeneous agents and their interactions to be described, at least in part, within the same level of description. Second, closures imply the existence of closed loops of interactions (i.e. topological determinations) among the participating agents and additionally the recurrence of certain sequences of specific interactions (i.e. behavioural determinations). Third, the use of the term "precarious network" hints that the autonomous construction is pretty fragile. If even one of its constituent agents does not fulfil its function, the whole construct might disintegrate. At least we can expect a significant and abrupt modification of identity in such cases. But the precariousness aspect is essential for the enactive approach as it ensures that the preservation of identity must somehow be an activity and not merely an inert property of the system. This is how a cognitive system is distinguished (see p. 13).

Undoubtedly, operational closures with distinct intrinsic characteristics and that "follow laws set up by their own activity" (Di Paolo et al., 2010, p. 37) are what we normally consider as individuals. The continuity of self-generated identity becomes the basis of a *perspective* an autonomous system has on its environment and a unique principle of sense-making subjugated to that identity and its persistence as a prime directive. Interactions across and within the boundary gain relevance and value in relation to this directive. But once the concept of identity and its continuity take root, individuation seems to have reached its end as the autonomous system will tend to resist further changes, or in other words, to exhaust its metastablity and reach a stable regime of its dynamics where it can regulate its interactions with the environment. To somewhat soften this apparent rigidity of autonomous constructs, Di Paolo (2006) proposes what he calls a system's *viability set* as the set of external perturbations and internal structural changes an autonomous identity can withstand without disintegration. We take this idea a definitive step further.

Can there be a third phase of sense-making that incorporates both dynamic boundary formation and operational closures? We argue that not only does such a phase exist, but that it is the case in the majority of actual phenomena. More often than not individuals are not rigidly fixed, but rather have continuously individuating *fluid identities*. Specifically, cognition as the activity of sense-making is never a stable set of competences that have exhausted all its potential for transformation, but is rather undergoing a continuous process of development.[7]

4.3.3. Fluid identities

The idea of fluid identities is a modification of the enactive approach to cognition based on replacing individuals with individuation. The requirement of precariousness at the basis of an autonomous structure can be relaxed in the following important manner: that operational closures need to be maintained continuously means that critically, the very property of closure is maintained, but it does not necessarily mean that *it is exactly the same closure that is maintained*. A closure C can be maintained as a series of individual closures $C_1, C_2, C_3, \ldots, C_i, \ldots$ that share among them some or most of their constituent agents but still significantly differ from each other. The precariousness can therefore be said to be maintained as a global property but is not locally maintained. The ordered set $[C_i]$ as a whole is then considered an individuating object with a fluid identity in the sense that it preserves most (but not all) of its invariant operational properties across short periods of time (e.g. while changing from C_i to C_{i+1}), but there is also a slow drift of these properties such that after a long time and many consecutive transformations (e.g. changing from C_i to $C_{i+k}, k \gg 1$) the said object has possibly become radically different from how it began. How is this possible? Conceptually, we already saw in Section 3.5 that individuals are assemblages whose constituting components are themselves independent individuals that affect and are affected by each other. Components can be plugged into and out of the assemblage without losing their individuality (because their individuality does not depend on the interactions but rather on their intrinsic properties). Fluid identity is in fact the only proper description of an assemblage or a continuously individuating agent. They may lose or gain components in the course of their interactions. Some of these interactions may bring forth operational closures that did not exist before, others may disrupt already existing closures and yet others may only replace one configuration of closure with another, possibly causing temporary but not fatal gaps in existing closures. All these movements are possible within assemblages and do actually happen all the time all around. That we tend to see the world in terms of stable identities is only a habit. Stable identities arising from strict operational closures are special cases of fluid identities where an assemblage has become (almost) crystallised or is just changing very slowly compared to its surroundings.

The phases of sense-making, from preindividual boundary formation, through fluid identities to autonomous closures, form in fact a single continuum of change that spans from ultimate disparity (disorder) to highly organised cognitive agents. Enclosures defined by information integration are preindividual and are characterised by a majority of contingent interactions over coordinated ones. Enclosures defined by operational closures are capable of sustaining an identity and are characterised by a majority of coordinated interactions over contingent ones.

On the thick borderline between these, exist fluid identities that are manifestations of more or less balanced proportions between coordinated and contingent interactions. These are volatile entities whose defining characteristics change across time. These may radically change their closure construct or even temporarily lose the strict closure property altogether without losing their overall distinctiveness from their environment in the long run. From the perspective of open-ended intelligence, these are the more interesting situations where new sense objects may arise out of no-sense but in association with previously established sense objects. This borderline seems to be where intelligence expands.

4.4. The resolution of disparity

As we have already mentioned earlier, the nature of intelligence intrinsic to individuation processes is associated with the resolution of disparity and problematic situations in a population of interacting agents, i.e. achieving higher degrees of compatibility. Compatibility is a general concept that distinguishes between ordered and disordered relations, structural, dynamic or both within the population of agents. Two agents are incompatible or disparate if their behaviours are entirely independent from each other. In interactions taking place between disparate agents, each will present for the other a source of unintelligible noise. No correlated or coordinated exchange of signals takes place in such a case. Consequently, the behaviour of one agent cannot be inferred from observing the other. Collections of disparate agents do not constitute systems as yet. They require an exhaustive description of all the unique agents and behaviours. A system arises from a collection of agents only when some degree of compatibility is achieved between its member elements. Systems can have more compact compressed descriptions (relative to their disparate initial state) because compatibility means a degree of regularity, similarity and recursion in structure and dynamics. The integration function $I(P)$ defined by Equation A3 in Appendix 1 can be considered as a simplified general measure of compatibility.

But compatibility thus understood cannot be the only factor necessary to qualify intelligence. A system with a highly compressed description would mean that its components are so highly compatible that it becomes redundant in terms of its properties and capacities ($I(P)$, accordingly, will be large). We need therefore to define a second factor we call *operational complexity*. Qualitatively, the operational complexity of a population P of interacting agents is the degree to which the overall system's states are differentiated. In other words, how many distinct behaviours it can present? A simplified measure of operational complexity $\mathrm{OC}(P)$ can be given in information theoretic terms and is developed in Appendix 2.

Clearly, a disparate collection of agents achieves the highest operational complexity since the states of all the agents are independent. But this extreme situation is actually not very intelligent (i.e. it is stupid). As each element operates on its own, the emergence of collectively integrated informational states is impossible. In terms of sense-making, ultimate disparity indicates no boundary formation at all, while ultimate integration indicates a redundant object with few or no inner states (i.e. no interesting behaviour). A measure of the intelligence embedded in the dynamics of an assemblage of interacting agents must therefore consider a balanced combination of both information integration and operational complexity. Based on the mathematical derivations in Appendices A and B, a measure of the open-ended intelligence operating in P can be expressed as a function of both the compatibility measure $I(P)$ and the operational complexity $\mathrm{OC}(P)$:

$$\mathrm{Int}_t(P) = \mathcal{F}(I_t(P), \mathrm{OC}_t(P)) \tag{1}$$

The subscript t here indicates that this measure is time-dependent. It changes in the course of individuation and does not necessarily achieve maximal values in relatively stable individuals. This conceptual formula helps to establish that the resolution of disparities and problematic situations is not captured only by achieving compatibility between the disparate components. The open-ended intelligence intrinsic to the formation of an assemblage is correlated to both its inner compatibility and operational complexity. Compatibility only reflects a degree of integration existing in a collection of interacting agents; it does not indicate *how* such integration is achieved. In order to resolve disparity and achieve compatibility, agents must *coordinate* their interactions. *Open-ended intelligence in individuating processes can therefore be associated with the coordination achieved by initially distributed disparate agents in the course of their interactions*. Coordination is what happens among agents that affect each other in a non-random manner but still maintain a significant degree of distinctiveness in their milieu. Whereas distinctiveness here means that an agent's behaviour is not redundant and cannot be entirely given in terms of other agents' behaviours. $\mathrm{Int}_t(P)$ approximates therefore the degree of coordination in an assemblage as it captures the evolution of both integration and inner distinctiveness of an assemblage. Mechanisms of coordination are therefore foundational to our approach and are further discussed next.

4.5. Coordination

We understand coordination as *the reciprocal regulation of behaviour given in terms of exchanging matter, energy or information among interacting agents, or, between an agent and its environment*. In the latter case, the very distinction of agent–environment already involves a basic level of coordination. Looking deeper into the nature of interactions among agents at a single-stratum P, we need to further understand the mechanisms by which populations of agents reduce disparity and incompatibility and progressively individuate towards integrated and coordinated higher level individuals. These mechanisms were already mentioned briefly in Section 4.3 as "habit forming".[8] Such mechanisms, we learn, are local and distributed over the population but need to be capable of achieving effects of global consequences.

Two major categories of mechanisms can be identified according to the aspect of the system that they affect[9]: (a) topology-modifying mechanisms and (b) behaviour-modifying mechanisms. Topology-modifying mechanisms manipulate the relative frequencies of interactions among agents depending on their particular nature. The principle common to such mechanisms is that interactions that contribute to compatibility and coordination will tend to increase in frequency, while those contributing to incompatibility will tend to be suppressed. The global topology of the network changes as links between compatible agents will become stronger, while links between incompatible agents will become weaker or disappear.

As a simple example, consider a group of people speaking a number of different languages. When interacting, people will tend to communicate with interlocutors speaking the same language and communication attempts with interlocutors who speak other languages will quickly become infrequent. Also, if there is no choice, people will seek those who speak a language that is similar to theirs and share some limited vocabulary. Another very well-known example is Hebbian learning in networks of neurones where synapses strengthen in correlation to synchronous firing of neurones before and after their synaptic connection (Hebb, 1968). The local modifications of topology achieve eventually global effects.

The significance of topology-modifying mechanisms is that interactions taking place over the network cause the modification of the structure of the network. Note also that the topological structure shaped by interactions further affects the future flow of interactions and therefore future global behaviours. By that, topology-modifying mechanisms realise a transductive process, as discussed in Section 3.4.

The second category of mechanisms has to do with behaviour modification. Agents can overcome their initial mutual incompatibility and become coordinated by constraining their own or each others' set of possible behaviours depending on their interactions.[10] In other words, they reciprocally determine or select each others' behaviours and by doing that, they bring forth mutual relevance and coordination.

Mutual modification of behaviour requires direct or indirect reflexivity among agents. If agent *A* affects the behaviour of agent *B*, but is not affected, directly or indirectly, by the modifications of behaviour it has initiated, there is no real sense in speaking about progressive resolution of disparity. Even in the case that the effects of *A* on *B* have reduced the incompatibility between *B* and another agent *C*, with no feedback to *A* of this reduction, the influence of *A* is only contingent and no recurrent pattern can emerge. If, however, some degree of reflexivity does exist, the exchange can eventually reach a relatively stable and recurrent set of interactions among the participant agents and an operational closure may emerge.[11]

Two observations can be made here. The first is that achieving coordination is primarily a cybernetic[12] selective process that involves feedback. The second conclusion is somewhat more complex; in order to participate in a coordinated assemblage, agents need to be reciprocally sensitive to the states of each other. We can see now why $\mathrm{Int}_t(P)$ corresponds approximately to higher degrees of coordination, but we can also see the limitation of $\mathrm{Int}_t(P)$, since it does not necessarily indicate the bidirectional information exchanges that are necessary to establish recurrent patterns. Supporting these observations is Edelman's discussion and research of re-entrant neural circuits (Edelman, 1987; Edelman & Gally, 2013; Tononi, Sporns, & Edelman, 1992).

The regulation of interactions whether by constraining the network topology or the actual behaviour of the agents can be thought of as a *meta capacity* of agents because they not only affect and are affected by other agents but can also regulate the manner by which they affect and are affected. According to Di Paolo et al. (2010, p. 39), the difference between structural coupling of an agent with its environment (or other agents) and the regulation of this coupling is the definitional property of a cognitive system. But such regulation is not designed. It gradually emerges in the course of interactions that are at least initially contingent. Therefore, we do not see merit in drawing sharp lines between systems that are cognitive and systems that are not when it is evident in many if not all cases that sense-making, the mark of cognition, is a matter of a gradual continuous process of individuation.

In summary, the underlying processes of sense-making can be understood in cybernetic terms. These are mutually selective processes distributed over populations of interacting agents. They "explore" and spontaneously "discover" novel coordinated interactions among the participating agents. A new sense consolidates, however, only when such "discovered" coordinated interactions become recurrent ("forming a habit"). The tendency towards the formation of recurrent patterns of interactions is not given *a priori*. It is itself an outcome of individuation as certain coordinated interactions contingently form operational closures or fluid identities that resist change to a greater or lesser degree. If there was absolutely no such tendency, there could be no coordination, no individual objects or persistent relations between objects, just disorder.

4.6. Perspective and value

The concept of value occupies a primary place in the discourse about the nature of intelligence. In Section 2.1, the ability of an agent to achieve goals is mediated by maximising rewards. The combination of a goal and environment creates for the intelligent agent a perspective by which all situations whether internal or external, and all agent–environment interactions, gain significance in terms of how they reflect on the achievement of the goal. Values can be generally described as the quantitative measures of significance and the dynamics of values guide the actions of the agent. In his analysis of intelligent agents, Legg (2008) writes:

> [. . .] We define an additional communication channel with the simplest possible semantics: a signal that indicates how good the agent's current situation is. We will call this signal the reward. The agent simply has to maximize the amount of reward it receives, which is a function of the goal. In a complex setting the agent might be rewarded for winning a game or solving a puzzle. If the agent is to succeed in its environment, that is, receive a lot of reward,

> it must learn about the structure of the environment and in particular what it needs to do in order to get reward. (Legg, 2008, p. 72)

Traditionally, intelligence is measured in terms of finding ways to maximise the reward (value) for various environments and goals. Of course, the value function itself may be subject to changes in time and additionally, strategies that consider short-term or long-term maximum rewards might be profoundly different. Still, as the commonly accepted concept of intelligence is understood, the manipulation of measurable value by the agent is what intelligence is all about and therefore value must be a given (see also Section 2.2).

The enactive theory of cognition follows a similar approach but with two important differences: (a) specific values are not *a priori* given but are self-generated by an operational closure and characterise an autonomous identity: "Sense making: Already implied in the notion of interactive autonomy is the realization that organisms cast a web of significance on their world" (Di Paolo et al., 2010, p. 39) (see also Section 4.3), and (b) the preservation of identity is the prime value of autonomous systems: "For enactivism, value is simply an aspect of all sense-making, as sense-making is, at its root, the evaluation of the consequences of interaction for the conservation of an identity" (Di Paolo et al., 2010, p. 45). Indeed, according to enactivism, specific value functions are not given, but there is a primal value which is the conservation of identity. Di Paolo et al. later define value as "[ ] the extent to which a situation affects the viability of a self-sustaining and precarious network of processes that generates an identity" (Di Paolo et al., 2010, p. 48), which makes it even clearer that there is an *a priori* value in place. In both approaches, value guides behaviour but is also a limit. Once achieved or maximised, the potential of the agent for further exploration is exhausted.

Though we accept that values are intrinsic to sense-making, we do not agree that values must precede any intelligent activity or sense-making in order to guide them, nor that they are necessarily preceded by the establishment of an autonomous identity. Rather, values are products of an ongoing individuation. Emerging values in the process of individuation carry their own problematic as they are initially non-coherent or even conflicting. A good example of the individuation of value is the negotiation over the price of a certain good in a marketplace. If the market is big enough, and the good is offered by a few vendors, the price of the same good can be negotiated in many places by different agents and reach significantly different values. However, information exchanged among buyers and sellers over the whole market will eventually minimise or eliminate the variation in the price.[13] When[14] in the course of individuation, values become relatively invariant, they become the characteristics of stable individuals. The effective regulation of such values by individuals can then be understood as the preservation of identity. Values can designate a certain relation or set of relations (e.g. body temperature relative to the environment, the skin colour of a chameleon, etc.) between an agent and its environment. When such value becomes regulated and therefore relatively stable, it guides general categories of behaviours such as adaptation (i.e. the modification of internal structure in response to perturbations), or niche construction (i.e. the modification of the structure of the environment in response to perturbations). The development of behaviours that belong to these categories is well accounted for by the conventional conception of intelligence.

Regulated values, by definition, resist change. Therefore, it is easy to understand why they are associated with identity. Identity is nothing more than a set of variables being kept within a certain range of values. Identity and values therefore co-define each other. Values in the course of individuation, in contrast, cannot be said to characterise an identity. In fact, they cannot be conventionally identified as values at all. In the preindividual state, there are no values, only *proto-values*.

In the multi-strata model of individuation, we describe in Section 4.2, every stratum individuates its own set of values that also reflect the different identities of agents that emerge in that stratum. The individuation of agents in any stratum S, however, does not depend only on horizontal interactions within that stratum. The relations of every stratum with its substratum S_{sub} and superstratum S_{sub} are mediated by values that emerge in these neighbouring strata. The substratum S_{sub} provides the component elements that constitute the assemblages in S. Inasmuch as these elements are more or less stable individuals, they have characteristic values that resist changes and perturbations that may be caused by interactions in S. In other words, the values that emerged at the substratum S_{sub} are selective (i.e. constraining) in regard to the interactions possible in S. In a similar manner, individuations that take place on the superstratum S_{sub} will tend to regulate the individuations on S by preferring certain interactions over others. For example, if an agent produced in S is frequently involved in assemblages emerging in S_{sub}, this will have a biasing effect on the distribution of agents within the population of agents in S. Changing the distribution of agents in the population exerts certain constraints as well as allowing certain degrees of freedom on the interactions taking place in S.

In summary, individuation at every stratum is subject to both bottom-up and top-down influences that are mediated by the values in neighbouring strata. Individuation at multiple simultaneous levels involves both evolutionary (bottom-up) and developmental (top-down) organisation. For example, a human organism in a social context is exposed to systems of individuating pressures that in turn affect biological parameters (e.g. stress) that affect the individuation of specific organs that in turn affect the individuation of cell populations and individual cells. A cell may produce a mutation, undergo destabilisation of its genetic operations as a result, and turn into a cancerous cell that is as stable as a healthy cell. This may disrupt a tissue or a whole organ and affect the performance of the affected human in her social context (e.g. disability and need for medical care). The division into strata reflected in our model is not an artificial construction though. It derives from the fact that complex individuation processes spontaneously produce a hierarchy of individuated entities because low-level simple assemblages are more probable (and therefore faster) to integrate into coordinated wholes than complex assemblages. This results in the emergence of a stratified process of individuation. See Simon (1962) for further discussion of this effect.

5. A non-concluding conclusion

Cognitive science and artificial intelligence research have made very impressive advances, in understanding and practically implementing systems with a wide range of intelligent capacities. Yet, most of the current theoretical thinking about intelligence and cognition is still limited to a problem-solving dogma, as argued in Sections 2.1–2.2. In this paper, we go beyond the identifiable cognitive competences that can be readily associated with specific problems or problem domains. We lay down philosophical and theoretical foundations to how intelligent systems such as brains, whole organisms, social entities and other organisations develop and scale. We shift the focus of investigation from intelligent agents as individual products to the intelligence intrinsic to their process of production, i.e. their individuation – what we call open-ended intelligence. We propose that such an approach provides important insights as to what differentiates intelligence that is open-ended and truly general from other goal-oriented and therefore limited types of intelligence. By that, we offer a significant extension to the conceptualisation and understanding of intelligence.

The principle distilled from this investigation is that *Open-ended Intelligence is a process where a distributed population of interacting heterogeneous agents achieves progressively higher levels of coordination. In coordination, here we mean the local resolution of disparities by means of reciprocal determination that brings forth new individuals in the form of integrated groups of agents (assemblages) that exchange meaningful information and spontaneously differentiate (dynamically and structurally) from their surrounding milieu.* This kind of intelligence is truly general in the sense that it is not directed or limited by an *a priori* given goal or challenge. Moreover, it is intrinsically and indefinitely scalable, at least from a theoretical point of view. We see open-ended intelligence manifesting all around us and at many scales; primarily in the evolution of life, in the phylogenetic and ontogenetic organisation of brains, in lifelong cognitive development and sense-making and in the self-organisation of complex systems from slime moulds, fungi and bee hives to human socio-technological entities.

Interestingly, open-ended generative intelligence is reflexively involved in the very process of describing it here in the individuation of concepts, models and perspectives explored above. And these, we learn, are always a work in progress. We conclude this paper therefore by highlighting problems and disparities in the form of a few challenging open questions that stimulate further research and may drive further individuation.

Measuring open-ended intelligence – The goal-oriented approach to general intelligence is particularly successful in providing a simple and reliable measure of fitness or success that can be directly associated with the level of intelligence an agent presents. In our case, however, measurement is much less obvious. In order to have a better grasp of the dynamics of intelligent individuating processes, more rigorous measures of individuation need to be developed. Because of the unique nature of individuation as a determining process, it is not entirely clear whether or not it can be generally quantified. Our point of departure for measurement is the concept of information integration that was developed by Tononi (2004, 2008) in a neuroscientific context as a possible explanation of consciousness. We use this concept in a somewhat different and more general way to quantify individuation. Measures based on information integration derive only from the probabilistic properties of the exchanged signals (Appendices A and B sketch preliminary steps in that direction). While this might be sufficient for low-level agents such as neurones, or similarly simple agents, they do not capture the full significance of affect between more complex interacting elements (e.g. human decision-makers) in the general case. This must necessarily involve a notion of the meaning embedded in the exchanged signals (i.e. what difference do they make for the agents). In other words, information integration is not sufficient to express the manner by which elements within an assemblage actually affect and are affected by each other. They merely reflect that such affective relations are taking place and to what extent. In order to quantify open-ended intelligence, a measure must be developed to reflect the degree of coordination achieved within a population of agents at each stage of individuation. Additionally, a measure needs to be developed to estimate relative stability and resilience of already formed individuals within a population. Such measure(s) will allow us to better understand and monitor the dynamics of individuation, turning points, disruptive elements and more.

Value systems and stratified individuation – Of special interest is to investigate the individuation of values. Values represent consolidated goals and are therefore highly significant in understanding the evolution of intelligent competences and sense-making. Values are signals that guide distinction mechanisms thus enabling adaptation and learning. In our understanding, values also mediate between different strata of individuation. The individuation of values seems to be an important key to further understand the individuation of intelligent systems across strata.

Towards a generative model – One of the more difficult and interesting challenges is to implement a simulation model of open-ended intelligence based on the concepts explored in this paper. Such an implementation will serve both theoretical and practical ends. It will help to better understand individuation and the transduction mechanism and it will help to understand or even discover general coordination mechanisms. It will help to appreciate the potential and limitations of scalability, and whether truly open-ended systems are practically possible and under what conditions. Importantly, it may also become a platform for specific applications.

Understanding coordination – We see the individuation of coordination as the manifestation of open-ended intelligence. One of the focuses of future research would be to investigate individuation processes in the light of the kinds of coordination they bring forth. For example, synchronisation is a very basic type of coordination having to do with the timing of activities and recurrent patterns of interaction. The phenomena of resonance are instrumental to understanding how agents that are initially not synchronised (i.e. disparate in the temporal sense) can gradually synchronise their interactions. Another important topic is to investigate the relations between the individuation of coordination within stratum and across strata.

Potential for application – Observing individual systems, we are often able to see in retrospect that the system evolved to address a specific problem (e.g. eyes, flowers, wings, courts, money, transportation systems, the Internet, etc.). But it is very difficult, if at all possible, to foresee what final purpose or goal a system might fulfil while it is individuating, when it is not a system as yet and the interactions among its prospective future components carry only marginally meaningful information. Open-ended intelligence therefore seems to be inherently unpredictable as to its final products and as a result difficult to be harnessed towards a useful purpose. It will be interesting to investigate the possible practical applications of individuating processes and whether they can be guided (Prokopenko, 2009). Of interest is also the hybridisation of goal-oriented and individuating approaches to achieve highly fluid intelligent systems.

Notes

1. This is possibly what Goertzel means in his emphasis on complex environments in the definition.
2. Observations can be entirely passive but interactions are necessary in order to observe the effects of the agent's actions on the environment.
3. A short introduction to assemblage theory can be found in: http://wikis.la.utexas.edu/theory/page/assemblage-theory.
4. Capacities also mean capacities to be destroyed. Certain interactions can amplify the internal unsettled intensities within an individual to the effect of its disintegration.
5. The scaling is not only structural but also temporal. Changes at different scales do not occur at the same frequency, also the stability of elements varies with complexity.
6. The designation "given" here is a simplification made for clarity. In fact, the elements in P_{sub} are never fully individuated and are affected by interactions taking place in its two adjacent strata as well.
7. Development generally means increase in intelligence in correlation to the complexity of situations and objects the system can make sense of. But the process is not necessarily monotonous; disintegration of already integrated structures can take place as well in the course of development. For example, when a theory is being replaced by a different, better theory that can explain and cohere more observations.
8. The tendency to form habits or repeating patterns of interaction is philosophically profound. It seems to indicate an ontological bias towards coordination over disparity, and more generally, of order over disorder. This goes back to transcendental empiricism being our point of departure. The co-emergence of observer and observed necessarily reflects an intrinsic bias (though temporary and local) towards order over disorder, otherwise neither observers nor observations could possibly emerge. Order, therefore is both self-evident and self-generative and so is the intelligence manifesting in it.
9. The distinction made here is clear only in the context of a single stratum but is much less apparent considering multiple strata as topological changes in one stratum lead to behavioural changes in the stratum above it.
10. For an early fascinating account of the idea of self-organisation in the sense described here, see Ashby (1962).
11. All forms of conditioning including self-conditioning belong to this category as they establish correlations between an agent's input and output signals.
12. The cybernetic nature of individuation was already discussed in Section 4.3, but here it is introduced in the more specific context of our model.
13. Such processes of individuation can become extremely complex. This example also demonstrates that considering a single price for a good is often a gross oversimplification. Prices of goods undergo an individuation process that is never exhausted especially if demand and supply are distributed and fluctuating.
14. Note that these are only simplified formulas that do not take into account the different sizes of subsets.

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Appendix 1. Information integration as a measure of boundary formation in a population of interacting agents

Given a population P of p_i interconnected agents, where $i \in [1, \dots, N]$, we wish to quantify how much they affect and are affected by each other. In information theoretic terminology, each agent p_i can either change its state independently of all other agents in P, or its state may depend on the states of other agents in P, or even be entirely determined by the states of other agents. The mutual information between two agents p_i, p_j is given by the formula:

$$\mathrm{MI}(p_i, p_j) = H(p_i) - H(p_i/p_j) = H(p_j) - H(p_j/p_i) \tag{A1}$$
$$= H(p_i) + H(p_j) - H(p_i, p_j) \tag{A2}$$

where $H(x)$ is the entropy involved in the state of agent x. If p_i and p_j are independent, $H(p_i, p_j) = H(p_i) + H(p_j)$ and then $\mathrm{MI}(p_i, p_j)$ would be 0. The mutual information would be maximum in the case that the state of one agent is fully determined by the other. In this case, the mutual information will be equal to min $(H(p_i), H(p_j))$.

For a set of agents p_i in P, the integration of the whole set would be given by the sum of the entropies of the independent agents p_i minus the entropy of the joint set P:

$$I(P) = \sum_{i=1}^{k} H(p_i) - H(P) \tag{A3}$$

In order to compare the degree of integration within a subset of agents to the integration between the said subset and the rest of the population, we divide the population of agents P into two subgroups of differing sizes: X_i^k and its complement $P - X_i^k$, where k is the number of agents in the subset X. The mutual information between X_i^k and its complement is:

$$\mathrm{MI}(X_i^k, P - X_i^k) = H(X_i^k) + H(P - X_i^k) - H(P) \tag{A4}$$

Formula (A4) measures the statistical dependence between a chosen subset i of k agents and the rest of the population. The *Cluster Index CI* of the subset X_i^k will therefore be given by:

$$\mathrm{CI}(X_i^k) = I(X_i^k)/\mathrm{MI}(X_i^k, P - X_i^k) \tag{A5}$$

CI measures the degree of distinctiveness of a subset of agents in P compared to the whole population in terms of information exchange.[14] For CI ≤ 1, there is no significant distinctiveness, while a subset with CI $\gg 1$ indicates a distinct integrated cluster. A threshold on CI can therefore be used to formally describe more or less integrated assemblages.

Appendix 2. The operational complexity of a system of interacting agents in a population

A simplified general measure of operational complexity can be given in terms of the average mutual information of subsets of P. Let P be a population of size M. Assume that P is isolated so its inner states are self-produced. We divide P into two complementary subsets X_j^k and $P - X_j^k$ of respective sizes k and $M - k$. The index j enumerates all possible subsets of size k out of X. The operational complexity OC(P) of population P can be given by:

$$\mathrm{OC}(P) = \sum_{k=1}^{M/2} < \mathrm{MI}\left(X_j^k, P - X_j^k\right) > \tag{B1}$$

where the mutual information is averaged on all subsets of size k. Subsets of very small size will contribute very little to OC(P), while subsets of sizes in the vicinity of $M/2$ will contribute the most complexity. Remarkably, OC(P) measure of complexity is based only on the extent to which subsets of the population affect each other and the statistical properties of the signals that agents within the population exchange. OC(P) therefore does not rely on an arbitrary measure of complexity imposed from outside the cluster.

Chapter 13

The Individuation of Social Systems: A Cognitive Framework

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The Individuation of Social Systems: A Cognitive Framework

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Abstract
We present a socio-human cognitive framework that radically deemphasizes the role of individual human agents required for both the formation of social systems and their ongoing operation thereafter. Our point of departure is Simondon's (1992) theory of individuation, which we integrate with the enactive theory of cognition (Di Paolo et al., 2010) and Luhmann's (1996) theory of social systems. This forges a novel view of social systems as complex, individuating sequences of communicative interactions that together constitute distributed yet distinct cognitive agencies, acquiring a capacity to exert influence over their human-constituted environment. We conclude that the resulting framework suggests several different paths of integrating AI agents into human society. One path suggests the emulation of a largely simplified version of the human mind, reduced in its functions to a specific triple selection-making which is necessary for sustaining social systems. Another one conceives AI systems that follow the distributed, autonomous architecture of social systems, instead that of humans.

Keywords: social systems, individuation, cognition, self-organization, communication, cognitive architecture

1 Introduction

In attempting to artificially emulate human cognition, one should not underestimate the degree to which cognitive activities are influenced (for better or worse) by the emergence and evolution of modern social systems. In this paper we argue that the latter operate as sui generis cognitive systems - autonomous, self-organizing loci of agency and cognition, which are distinct from human minds and manifesting behaviors that are irreducible to their aggregations. Though not biologically embodied, the manner these agencies individuate and their mode of operation is analogous to many other self-organizing processes of life.

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We believe that while the most researched paths towards AI/AGI development address the fundamental aspects of the cognitive architecture of an *individual* human mind, they still amount to a somewhat narrow conception of cognition. We wish to present here a different, complementary perspective of cognition, one which originates from a sociological systemic view. From there, we derive a framework for a socio-human cognitive architecture that radically deemphasizes and simplifies the role of individual human agents required for both the formation of social systems and their ongoing operation thereafter. Naturally, the resulting view of the functioning of human agents as facilitators of social systems, is as partial as the one that focuses on individual minds. It may however open a potentially faster route for implementing AI systems able to generate outcomes comparable to those that are achievable for contemporary human agents in the context of social systems.

Our explication is based on Niklas Luhmann's (1996, 2002, 2012) theory of social systems, which we link with the ancient Heraklitian view of reality as ontologically constituted of processes instead of objects and with Gilbert Simondon's (1992) theory of individuation. This results in an understanding of social systems as complex sequences of *occurrences of communication*, which are capable of becoming consolidated to the degree in which they start to display an emergent adaptive dynamics characteristic to cognitive systems - and to exert influence over their own mind-constituted environment.

2 Individuation of Cognitive Agents

In our understanding of social systems as cognitive systems we shift from an object-oriented Aristotelian ontology to a process-oriented one, moving away from individuals as primary ontological elements whereas all transformations are secondary, to *individuation* (Simondon, 1992; Weinbaum & Veitas, 2016, 2016a) as the primary ontological (or more accurately ontogenetic) element. Individuation is a process where the boundaries and distinctions that define individuals arise without assuming any individual that precedes them. Individuation is a primary formative activity whereas individuals are regarded as merely intermediate and metastable entities, undergoing a continuous process of change.

In this view, the individual undergoes a continuous process of transformation and is always pregnant with not yet actualized and not yet known potentialities of change. According to Simondon, an individual is not the rigidly well defined Aristotelian element with a priori given properties, but a plastic entity, an on-going becoming. In (Weinbaum & Veitas, 2016a) the authors discuss in length the mechanisms of individuation and specifically how local and contingent interactions progressively achieve higher degrees of coordination among initially disparate elements and by that bring forth complex individuated entities with agential capabilities.

We argue that individuation can be understood as a general process of *cognitive development* once we consider cognition as a process of sense-making that facilitates spontaneous boundary and distinction formation. This approach is supported by the theory of enactive cognition that sees in sense-making the primary activity of cognition (Varela, Thompson & Rosch, 1992; Stewart, Gapenne, & Di Paolo, 2010; De Jaegher & Di Paolo, 2007).

We follow this notion but introduce the more radical idea that sense-making is the bringing forth of a world of distinctions, objects and entities and the relations among them. In that, sense-making precedes both subjects and objects and is necessary to their emergence. In this very sense we draw the line that associates sense-making to individuation: sense-making thus understood, precedes the existence of consolidated cognitive agents to whom the activity of sense-making would be conventionally attributed. Even though there is `nobody there' as yet in the conventional sense, processes of individuation constitute a distributed and progressively more coherent (as boundaries and distinctions are formed) loci of autonomous cognitive activity. Individuation is thus a general process of cognitive development taken out from its relatively narrow psychological context and projected into the much broader context of general systems. Sense-making entails crossing the boundary between the unknown and the known through the formation of tentative *perceptions* and *actions* consolidating them together into more or less stable *conceptions*.

Individuation as an on-going formative process, manifests in the co-determining interactions taking place within heterogeneous populations of interacting agents. These populations are the "raw materials" from which new individuals emerge. The sense-making activities are distributed over the population and have no center of regulated activity or synchrony. Coordination - the recurrent mutual regulation of behaviors is achieved via interactions that are initially contingent. These interactions are necessary for the consolidation of any organized entity or system. We see then a strong parallel between cognitive development and individuation bringing forth actual agents --be them biological organisms, social systems, AIs, or any other. Consequently, in this very broad sense that we find particularly attractive in the context of transdisciplinary research we can assign cognitive agential competences to general systems applicable to diverse categories and scales.

3 Social Systems as Cognitive Individuals

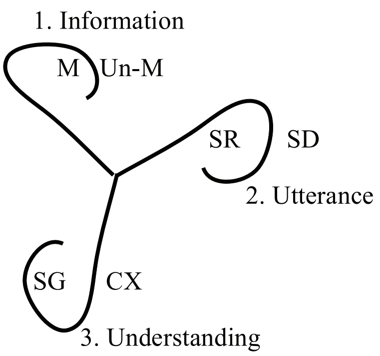
We can now apply this rationale to social systems. By a 'social system' we mean here any metastable form of social activity --such as organizations, projects, social movements, economies, governments, states, religious organizations, cultural organizations, discourses, narratives, linguistic activities such as conversations, stories, reports etc. Using Luhmann's theory of social systems as our point of departure, we will a) demonstrate the individuation of social systems, i.e. the sense-making activity that brings them forth, and b) identify social systems as the metastable individuals that they are. This will support our thesis that social systems can be considered as loci of cognitive activity or in other words as distributed cognitive agents.

According to the Niklas Luhmann's theory of social systems (2002, 2012) events which forge the social reality happen as single occurrences of *communication*, while each such occurrence is combination of three difference-making selections: (a) a selection of *information*, (b) a selection of the *utterance* of (a form to carry out) that information and (c) a selection of *understanding* of that utterance (Luhmann, 2002:157).

Once such three selections have been made as combined together, they form a unity of a communicative event, which temporarily becomes an individual by itself. This means that it distinguishes itself from its environment (i.e. any other processes or events) by the means of three provisional boundaries, which the event sets forth: a) an 'information-making boundary' between the marked and unmarked sides of a distinction being made (Spencer-Brown, 1994), i.e. delineating the selected information (marked - M) and the non-selected one (unmarked - Un-M), (b) a 'semiotic boundary' (Lotman, 2001) between the thus created *signified* (SD) and a particular *signifier* (SR) selected to carry the information, and (c) a 'sense-making boundary' between thus created *sign* (SGN) and the *context* (CX), i.e. delineating the understanding of information within its situation (Lenartowicz, Weinbaum & Braathen, 2016).

The three selections and corresponding boundaries of an event make the communication available to interact with or to be referred to by another communicative event constituted by another triple selection. E.g., the inside of a distinction may select another marked and unmarked side of an information boundary in another instance of a communicative event; the form that was selected as an utterance may be reused in the future, or may be referred to as the selected information; the context side of the sense-making boundary may be re-selected in the understanding of a following communication, etc.

Once recorded or remembered, all communicative events and all selections become endlessly available to be referred to, independently of their proximity in location or time of utterance. This allows them to freely interrelate in a variety of ways that give rise to the emergence of countless transient, original sequences and configurations. However, closed networks of communication, which are typical to humans, are likely to tighten the intertwining and associative relations of communicative events to such a degree that they converge into self-reinforcing recurrent sequences (Lenartowicz, 2016). Once stabilized, such assembled sequences may become quite difficult *not* to be related to by following specific instances of communication, even if in a form of negation, or critique. Thus, out of ephemeral instances of single primitive communicative events, complex individuated sequences and patterns arise. We call such individuals *social systems* and we consider the process of their self-organization to be a clear case of individuation as described in section 2 (Lenartowicz, Weinbaum & Braathen, 2016).



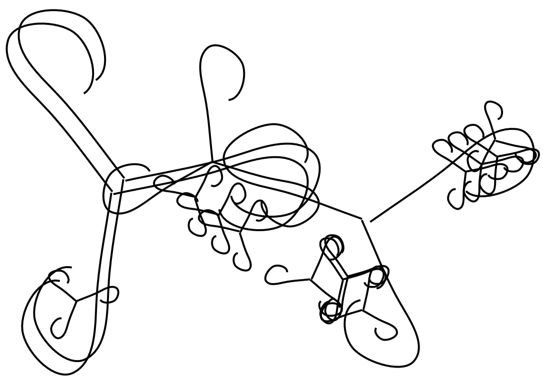


Figure 1: (A.) A single occurrence of communication and (B.) self-organization of a sequence of communication

By repeatedly referring and being referred to (with some degree of variation) the elements of social systems maintain both continuity and coherence while they undergo a continuous individuation. Coherence is maintained and reinforced due to distinction-based composition: since, while recurring, a sequence of communications repeats (with high probability) its previous selections, in a manner similar to the dynamics of Markovian processes. Boundaries that are initially contingent, become reinforced and stabilized. On account of their repetition, a social system can be said to develop perceptions (i.e. reappearing selections of information and understanding), actions (i.e. reappearing selections of utterance) and conceptions (percept – action associations) that dynamically bind them. Each such assemblage thus becomes a locus of identifiable cognitive activity, temporarily stabilized within a flux of communication.

4 The Role of Human Cognition

The selections needed for a social system to individuate i.e. the three selections of information, of utterance, and of understanding, are all performed by other individuated cognitive systems, namely:

human beings. Once a certain degree of coherence of the social system is achieved, this activity is nudged by the internal pattern of that system, which orients and guides the human-made selections. The mental environment provided by humans actively facilitates the further individuation of the system by searching for and/or initiating new instances of communication that promote clarity, coherence and the determination of yet undetermined details in previous communications.

The necessity of the engagement of human cognition and actions may call into question both the actual agency, which we attribute to social systems, and the appropriateness of the concepts of self-organization and individuation being applied to them. However, it must be emphasized that the power of influence of a single human individual over the social organization she is part of is always relative and dynamic. Whether water will wash a seedling out, or will be consumed towards its growth, is contingent on the relative difference of their mass and capacity. By analogy, an individual person, who may normally be capable of generating an unprecedented occurrence of communication, is typically much less capable, or incapable at all, of being oblivious and restraining from contributing to the production of a fully blown, massive social system, such as a culture, an economy, a discourse, or a paradigm. The reason lies in the relative difference of strength between the two individuals: human and social. When the social system is at the very beginning of its potential individuation, consisting of a single, hardly contextualized occurrence of communication, the human individual may freely influence its shape. But when the social system becomes massive and its pattern is confirmed by an immense number of other communications, selections made by the same person are much more likely to simply follow the groove. Additionally, if a single selection *does not* follow the pattern, typically it will neither stop the operations of the system, nor reorganize it. The overwhelming presence of other instances of communication that *do* follow will suffice for it to continue. It is the power of large numbers and memetic imitation that helps to consolidate the social system.

Taking into account a variety of powerful factors that guide all the linguistic activities of humans: (a) the relative simplicity, associative coherence, frequent recurrence of the cognitive operations once they become consolidated in a social system (b) the rarity of context-free (e.g. completely exploratory and poetic) communications that is reinforced by the density and entanglement of all “language games” in which contemporary humans are all immersed in, and (c) the high level of predictability of human selection-making inputs observable from the sociological standpoint; it will be reasonable to set the boundaries of our modeling of the general phenomena of human cognition in such a way, which delineates the dynamics of two different kinds of individuating cognitive agencies operating at different scales: the human individual and the social system. Instead of reducing all cognitive activities to the human individual we can clearly distinguish cognitive agencies operating at different scales.

5 Conclusion

Taking into account the strength of the influence that the cognitive operations of social systems are capable of exerting on the cognitive operations of humans, as well as the relative simplicity of the role of the humans once it becomes reduced to the triple selection-making, it seems worth to explore the possibility that in the attempt to replicate human cognition in AI systems a similar split architecture could be introduced.

While the implication that individual human beings compliantly follow patterns laid out by social systems may invoke resentment or even denial, a similar degree of socially induced amenability might prove desirable, if displayed in robots. Provided that a deliberate consensual choice can be made in respect to the kinds of social systems which would be beneficial to humans and human communities in general, an artificial cognitive architecture designed specifically to follow the operations of social systems could probably minimize the threat of AI systems becoming "too creative" or "too independent" and thus posing a threat from the perspective of human societies.

Yet, the interpretation of social systems as individuating cognitive systems opens up possibilities other than just the one of designing AI as contributors of the triple selection-making. Another interesting possibility is to conceive AI systems that follow the distributed architecture of social systems, instead of that of individual human cognition. In this approach an intelligent artificial architecture would be envisaged as a self-organizing cloud of occurrences of communication, which seeks self-consolidation and expansion via opening up of triple selection-making opportunities for other agents: humans, software systems or machines. Seen from this perspective, and taking into account the open-ended nature of individuation and evolution, it is conceivable that such an individuating system may emerge out of any simple autonomous organization.

And, clearly, in the most sophisticated and unpredictable implementation both paths would be followed simultaneously: designing a multi-scale AI system that involves both the individual and social perspectives we explored. Artificial systems could be designed to implement both the selection making populations of individual agents and a selection-constituted distributed systems -- a complete artificial social reality might thus be created.

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Chapter 14

Spooky Action at No Distance

Spooky Action at No Distance

On the individuation of quantum mechanical systems

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Recent experiments have perfectly verified the fact that quantum correlations between two entangled particles are stronger than any classical, local pre-quantum worldview allows. This is famously called the EPR paradox first conceived as a thought experiment and decades later realized in the lab. We discuss in depth the nature of the paradox and show that the problematics it presents are first and foremost epistemological. After briefly exploring resolutions to the paradox that past many decades of discourse still remain controversial, we argue that the paradox is rooted in the failure of our current metaphysical scheme, being the foundation of our knowledge, to accommodate and cohere our knowledge of the phenomena of entanglement. We then develop and make the case for a novel and more fundamental resolution of the paradox by changing the underlying metaphysical foundation from one based on individuals to a one based on individuation. We discuss in detail how in the light of this new scheme concepts central to the paradox such as realism, causality and locality are adjusted to the effect that the paradox is resolved without giving up these concepts so fundamental to our thinking. We conclude with a brief note about the important role of metaphysics to the progress of knowledge and our understanding of reality.

Keywords: quantum entanglement, EPR paradox, individuation, metaphysics, realism, locality

1 Introduction

Every year the prestigious web magazine Edge[1] pronounces a yearly question and invites distinguished thinkers from diverse disciplines to answer. The 2016 Edge question was: "What do you consider the most interesting recent scientific news? What makes it important?". My motivation for writing this paper came from reading quantum physicist professor Anton Zeilinger's[2] answer to this question. A quote from Zeilinger's answer is in place:

> The notion of quantum entanglement, famously called spooky action at a distance by Einstein emerges more and more as having deep implications

[1] See: http://edge.org/response-detail/26790.
[2] See: http://edge.org/memberbio/anton_zeilinger.

> for our understanding of the World. Recent experiments have perfectly verified the fact that quantum correlations between two entangled particles are stronger than any classical, local pre-quantum worldview allows. So, since quantum physics predicts these measurement results for at least eighty years, whats the deal?
>
> The point is that the predictions of quantum mechanics are independent of the relative arrangement in space and time of the individual measurements. Fully independent of their distance, independent of which is earlier or later etc. One has perfect correlations between all of an entangled system even as these correlations cannot be explained by properties carried by the system before measurement. So quantum mechanics transgresses space and time in a very deep sense. *We would be well advised to reconsider the foundations of space and time in a conceptual way.* (My added emphasis)

My goal in this paper is exactly this: a reconsideration of the conceptual foundations of realism and specifically of space in the light of the phenomenon of quantum entanglement. I will apply Simondon's theory of individuation and Bergson's conceptualization of space in order to reexamine what Einstein called "spooky action at a distance" and more specifically the notion of physical locality and its underlying metaphysical assumptions. The examination will lead first to developing and arguing for an alternative metaphysical scheme that coherently accommodates both quantum and classical phenomena. This alternative scheme adjusts our understanding of realism and will further make a case for developing a new non-conventional (and somewhat surprising) intuition about the reality of space and how it is represented. With the renewed conceptualizations developed, it is shown that nothing spooky is taking place in quantum entanglement; at least not spooky in the sense that Einstein meant. The resolution of the paradoxical action at distance responsible for innumerable sleepless nights of physicists and philosophers alike, is thus shown to be possible by adopting the alternative metaphysical scheme we develop here. With it we can finally cohere our knowledge about quantum entanglement with the rest of our knowledge about natural phenomena.

The second section gives a short description of the EPR paradox and the violation of Bell's inequalities. It will then discuss more in depth the meaning of this violation and the problem of non-locality and causation in quantum entangled systems. The section concludes by proposing a conceptual revision of the problem and sketches the metaphysical adjustments that are needed in order to resolve the paradox. The third section starts with a critique of Boole's conditions of possible experience. Next, it presents in brief Simondon's theory of individuation and the application of the concept of individuation to entangled systems. It then develops in depth the new conceptions of realism and causal explanation in the light of a metaphysical scheme based on individuation. The fourth section is dedicated to the individuation of space and how it reflects on entangled systems. It starts with general considerations regarding the concept of locality as it is currently understood and its limitations. It then explores Bergson's metaphysics of space and applies it to argue that in the case of entangled systems also space and locality are subject to individuation. By that the development of the alternative metaphysical scheme started in section 3 is completed. A discussion of the philosophical implications on understanding locality in entangled systems follows. The fifth and last section is a summary of the whole conceptual revision developed in the paper and how it resolves the paradox. It concludes with a short note on the role of metaphysical investigation in cohering our knowledge about reality.

2 The EPR paradox and the nature of quantum phenomena

2.1 A short account of the EPR experiment and Bell's inequalities

Around 1935, a paper authored by Albert Einstein, Boris Podolski and Nathan Rosen (Einstein, Podolsky, and Rosen, 1935), presented a thought experiment that claimed to demonstrate that the quantum wave function does not provide a complete description of physical reality. This has come to be known as the EPR paradox. The thought experiment was set to show that a measurement of the location and momentum of two entangled physical particles can be performed in a manner that violates Heisenberg's uncertainty principle. Two physical particles are prepared in advance in such a manner that they are quantum entangled. The peculiar nature of quantum properties is such that for an entangled system of particles a certain property cannot be described or measured independently for each particle but only for the joint system as a whole[3]. Skipping the technical and mathematical details, the gist of the experiment was that once the entangled particles are physically separated in space, one can measure accurately the location of one particle and the momentum of the second. Since they are entangled, the momentum of the first particle can be accurately derived from the measurement of the second. This way one can measure both the location and momentum of one of the particles more accurately than what is permitted by the uncertainty principle. Two possible explanations are suggested: *a*) Either the measurement performed on one particle affects instantaneously the other over an arbitrary distance to prevent the violation – what came to be coined as "spooky action at a distance"[4], or, *b*) the information about the outcome of all possible measurements is already present *in both particles* to begin with and is encoded with some 'hidden variables' that were set once the particles were brought into entanglement and carried along independently by each. To the authors, the possibility of non-local effects arising in entangled systems was unacceptable; which led them to the conclusion that the description of the entangled system of particles as a single non-decomposable system must be incomplete. In other words, the particles are singled out by hidden variables local to each. The incompleteness of quantum theory is that it falls short of predicting accurately the states of entangled particles though these are determined by their hidden variables. A proper local hidden variables theory that would presumably do better is needed to replace quantum theory. Such a hidden variable theory will affirm what is called *local realism* also for quantum phenomena. Where in

[3]We will later see that this very peculiarity is central to the question of whether or not in the case of quantum entangled systems one can speak about two independent particles.

[4]Such effect however does not violate special relativity because no information is exchanged between the particles.

brief, locality basically means that no instantaneous action at a distance is possible and realism claims that physical particles possess definite properties irrespective to whether or when actual measurements are performed to obtain these properties. Thus a local realist quantum theory will cohere our knowledge about physical phenomena both classic and quantum under the same fundamental principles of locality and realism. The EPR experiment can be seen therefore as an attempt to 'tame' quantum phenomena into an already established dogma.

In a seminal paper published in 1964, John Bell, (1964) came with a theorem stating that any physical theory that assumes local realism must satisfy certain conditions called Bell's inequalities. Bell developed a somewhat different version of the experiment described in the EPR paper using particle spins rather than location and momentum as the measured quantum properties. He showed that the predictions of quantum theory regarding measurements performed on entangled systems violate his inequalities. The consequences of such violation, if verified by actual experiments, will exclude any possibility of a local realist hidden variable theory to reproduce the results predicted by quantum theory.

Actual experiments equivalent to the EPR experiment were conducted since 1976 with overwhelming evidence that measurements of quantum entangled systems do violate Bell's inequalities. In the course of research various loopholes were discovered in the experiments and new setups were progressively devised to avoid them. In October 2015 the first loophole-free experiment was reported (Hensen et al., 2015), directly testing Bell's theorem and demonstrating yet again the peculiar nature of quantum phenomena. Probably it is this outstanding result that inspired Zeilinger's answer.

There is rich literature covering the complex physics of quantum entanglement which does a much more thorough job than the brief treatment provided here. The important point however is that it has become finally evident by experiment that the phenomenon of quantum entanglement presents behaviors which are not coherent with our common intuitions regarding space and time. As Zeilinger concludes: "Thus, it appears that on the level of measurements of properties of members of an entangled ensemble, quantum physics is oblivious to space and time." Trying to settle this apparent discrepancy and understanding the meaning of this radical statement is the point of departure of this paper.

2.2 Bell's inequalities and Boole's conditions of possible experience

To develop a deeper understanding of Bell's inequalities and their meaning it is important to note that they do not describe a quantum physical principle or even a physical principle. Bell's inequalities rather state the conditions that must hold regarding knowledge that can be obtained by statistical sampling of a population of objects for which local realism holds. I.e. a population of objects that possesses (and are defined by) measurement independent properties and interact only according to the principle of locality. Pitowsky shows in (Pitowsky, 1994) and more extensively in (Pitowsky, 1989) that the Bell inequalities are a special case of *Boole's conditions of possible experience*. Given a certain body of data concerning a population of objects, let $P_1, P_2, \ldots, P_n$ be the probabilities given of certain events. And where an event can be understood as the existence or non-existence of a certain set of properties in a single object. P_i therefore is the frequency of finding a set of properties i in the population. In the trivial case, where no relations obtain among the events, then the only constraints imposed on the probabilities is that $0 \leq P_i \leq 1$.

However, if the events are logically connected, there are further equalities or inequalities that obtain among the different probabilities. Let us consider a simple example: suppose we get an urn with many balls some of which are wooden (event $E1$) with probability P_1 and some of them are red (event $E2$) with probability P_2. Now, we sample balls from the urn and we are interested in the frequencies of events such as $E1$ or $E2$ but also in the frequency P_{12} of sampling balls which are both wooden *and* red (event $E1 \cap E2$). These three events here are not logically independent of course and in addition to the trivial inequalities $0 \leq P_1, P_2, P_{12} \leq 1$ we also have: $P_1 \geq P_{12}$, $P_2 \geq P_{12}$. Also the frequency $P_1 + P_2 - P_{12}$ of sampling balls which are either wooden *or* red (event $E1 \cup E2$) must hold: $P_1 + P_2 - P_{12} \leq 1$. The various versions of Bell's inequalities[5] and other similar sets of constraints that are used in quantum theory are obtained in a similar way by applying logical rules to probabilities of properties and events (the occurrence of a single property is the simplest kind of event). Boole (Boole, 1862; Hailperin, 1986) called these constraints "conditions of possible experience" because any observation/experience that involves probabilistic sampling of real properties of objects must logically stand to these conditions.

Remarkably, none of Boole's conditions can be violated when all the relative frequencies are measured *on a single sample of the population*. In the above example suppose that we take 100 balls out of the urn. We discover that 60 are wooden and 75 are red and 32 of them are both red and wooden. In terms of frequencies, $P_1 = 0.6$ and $P_2 = 0.75$ and $P_{12} = 0.32$. But then $P_1 + P_2 - P_{12} > 1$ which is a logical impossibility because in such a case there must be a ball which is 'red', 'wooden' but not 'red and wooden'. Without exception, as long as we make all measurements on a single sample, similar logical impossibilities will arise in conjunction with the violation of one or more of Boole's conditions also in arbitrarily complicated cases. However, if for some reason or other, the measurements of logically dependent events are not made on a single sample, violations of Boole's conditions may occur. Pitowsky, (1994, pp. 105-107) lists a few reasons why such violations may happen:

1. **Failure of randomness** – A violation of Boole's conditions may occur if one or more of the distinct samples fail to represent the distribution of properties in the overall population. The population might not be well mixed, the samples too small etc.

2. **Measurement biases** – Even if the samples are perfectly random, violation can still occur if the observations are somehow biased or disturbed because they are not well performed. In the above example we could imagine that the property 'red' is

[5] The Bell inequalities involve three primitive properties and their combinations. See (Pitowsky, 1994, pp. 103-104)

observed under certain lighting conditions while the property 'red and wooden' is performed under different lighting conditions.

3. **No distribution** – According to the law of large numbers, the relative frequency of a property in a finite random sample approximates, with high probability, the frequency of that property in the larger population. For that reason we expect Boole's conditions to hold even when relative frequencies are measured over distinct samples. But this consideration hides the assumption that the hypothetical population we examine does have an *a priori* distribution of properties that is *the cause* for the measurements obtained. But according to Hume's empiricist skepticism (Hume, 2012), the attribution of causal explanation between two events cannot be logically justified. Specifically, the attribution of relative frequencies to an *a priori* distribution of the population is merely an induction. The failure of Boole's conditions may therefore arise even when samples are sufficiently randomized and measurement biases have been eliminated simply because the habitual assumption about a causative explanation is not valid. It might well be that there is no population with stable properties and consequently no distribution. There is also the case that somehow properties do not exist independently of measurement. This consideration is not merely technical like the first two and will be further discussed later.

4. **Mathematical oddities** – Within certain mathematical considerations of how the probability measure is defined, there are exotic cases of distribution in a continuous probability space (as opposed to discrete populations of objects) where there is a logical possibility of the violation of Boole's conditions. But this option will not be our concern here as it can hardly apply to natural phenomena.

The nature of quantum phenomena is such that certain sets of properties are complementary (e.g. the position and momentum of a particle) which means that according to the uncertainty principle, these properties cannot be measured simultaneously, or, at least we do not know how to perform such simultaneous measurements. Still, these properties do hold between them logical dependencies such as those discussed here. Interestingly, Pitowsky notes that when we do know how to perform simultaneous measurements of a certain set of properties (i.e. in the case they are not complementary), there is no violation of Boole's conditions even when the measurements are performed on distinct samples (Pitowsky, 1994, p 109). However, testing the behavior of quantum entangled systems specifically involve complementary properties for which no method for simultaneous measurement is known to exist. In such cases, it is necessary to perform measurements over multiple distinct samples. It is in such cases and only in such cases that quantum theory predicts outcomes that are in violation of Boole's conditions. A violation of Boole's conditions therefore is unique to those cases where no method for simultaneous measurement is known to exist.

This analysis clearly exposes the serious threat that quantum phenomena presents to the consistency of our knowledge and understanding of natural phenomena. The paradox goes beyond physics and one needs therefore to come up with a convincing explanation for the violation of Boole's conditions. In other words, to plausibly show that the arising logical contradictions involved are only apparent, that there is no actual threat to our logical conceptions. Of the four categories of explanations mentioned above, we can quite safely discard the fourth category of mathematical oddities as a relevant candidate, if only because of Ockham's razor (Pitowsky, 1994, p 119). In regard to the first category – failure of randomness, this is basically a technical issue that early experiments were ridden with. New measurement methods and the progressive elimination of various loopholes as reported in (Hensen et al., 2015), pretty much eliminate this category as well. We are left with the second and third categories which are more interesting because in contrast, they offer explanatory interpretations of quantum mechanics that challenge our most basic intuitions.

2.3 The problem of non-locality and realism in entangled systems

The second category of explanations involve measurement biases of two kinds: *a*) a bias that depends on the measurement equipment and method and that can be eliminated by improved technology, and *b*) a bias which is built-in within the setup of experiments that cannot be removed by improved technology. Explanations that involve measurement biases of the second kind are usually referred to as hidden variables theories. It is hypothesized that such variables which are not defined in the current quantum theory (i.e. hidden from it) display dynamic changes that bias the results of measurements in such manner as to produce *the appearance of violation* of Boole's conditions. In other words, the violation is an illusion only indicating the incompleteness of the current theory. Were we in possession of a better theory that exposes the hidden variables, its predictions wouldn't have violated Boole's conditions at all. As already discussed in subsection 2.1, experimental reality is quite embarrassing in this respect: all hidden variable explanations coherent with experiment involve non-locality, i.e. effects that propagate instantaneously across arbitrary distances. Again, it is not that something is fundamentally wrong with hidden variables explanations; they simply do not add anything that explains away the disturbing peculiarities of quantum entanglement. Instead, they just re-describe them in different terms leaving our deepest intuitions about locality in question. Still, having to choose between logical contradiction and non-local effects, the latter is the lesser evil.

We are left to consider the third category of explanations. As was already discussed above, the third category brings up the problem of realism. Given the violation of Boole's conditions in the case of measuring complementary quantum properties, and given the inconvenience invoked by non-locality as a possible justification, we may consider the alternative that an *a priori* distribution of the population of events/objects under examination does not exist and if so, distinct samples *do not represent* a single hypothetical population in possession of stable properties that exist independently of measurement or other interactions. As Pitowsky puts it:

> What is at stake is the idea of causality. The 'no distribution' approach takes the view that certain phenomena, or more precisely, certain aspects of

certain phenomena, have no causal explanation. They simply occur and that is it.

This approach is not a radical departure from the general empiricist suspicious view of causal explanations. The function of a scientific theory, as perceived by the empiricist, is to organize data and predict. Causal explanation is a fiction of the human mind riding on a theory's ability to organize and predict. Which intuition locality or realism would be worth keeping and which could be sacrificed to make the behavior of quantum entanglement a 'possible experience'? At this point, this issue is a matter of controversy among both physicists and philosophers.

The philosophical riddle presented here is apparently an epistemological one. A fundamental part of the physical world - the world of the very small, behaves in a way that seems to put in doubt the human ability to create a unified and coherent corpus of knowledge. We cannot do with 'impossible experiences' running havoc in our laboratories. Given the history of research in quantum physics it is not very plausible (though not ultimately refutable) that some fine detail of the theory has escaped us and once it will be discovered, everything will be put in order. The controversy regarding non-locality and realism that remains unresolved is philosophically very disturbing. In as far as the empiricist physicist is concerned, physics is okay; quantum theory is one of the most successful scientific theories ever devised. It is our conceptions that need revision.

2.4 A conceptual revision

The currently accepted idea is to either give up locality or realism. As each alone seems to resolve the paradox, it would seem reasonable that choosing only one minimizes the 'damage' inflicted on our sensibilities. But perhaps there is a way to somehow give up both in their current form and instead rethink their deeper meaning in a way that will shed new light on possible experiences and will allow us to keep both albeit with a slight yet profound new meaning. In the following I am going to describe and defend such an alternative approach. We start with the claim that the paradox we are facing is not merely epistemological, but is rooted in the very concept of space insofar as it is applied to locality, and in what we conceive as real insofar as it is applied to the properties of physical entities. In other words, the impasse the paradox presents is metaphysical. It is metaphysics that shapes our intuitions and it is metaphysics that needs to be adjusted. Here is a sketch of the proposed adjustment:

1. In developing Boole's conditions of possible experience, Aristotle's principle of the excluded middle is implicitly taken as given. That is, a property either exists or does not exist in any object or event of interest. Our criticism of Boole's conditions is that while this assumption may be legitimate for abstract objects and properties, its automatic extension to physical objects and events is far from warranted. Independently of one's knowledge about a certain property, it is conceivable that properties undergo a process of genesis or differentiation and are not *a priori* given or just appear instantaneously.

2. Simondon's theory of individuation proposes a metaphysics of formative processes that replaces the metaphysics based on fully formed individuals on which Boole's conditions are based. The idea of individuation allows to replace the *hard realism* described by Boole's conditions with a *soft realism* where properties and entities defined by properties are not given *a priori* as fully formed individuals but undergo a process of coming into being – individuation. The violation of Boole's conditions when applied to undifferentiated properties then merely indicates the inadequacy of hard realism as a description of quantum phenomena whereas soft realism is entirely consistent with it.

3. In subsection 3.3, soft realism is shown to be a position midway between the commonly accepted hard realism and the non-realist position discussed in subsection 2.3. Replacing hard realism with soft realism and individuals with individuation carries profound consequences on understanding causation in quantum mechanical systems and brings us closer to a consistent understanding of entanglement (and other quantum effects as well).

4. The principle of locality considers spatial distinctions and effects over distances. If spatial distinctions are subject to processes of individuation like other physical properties, it is possible that our conception of the spatial separation at the basis of locality requires refinement. Such refinement is proposed by Bergson's metaphysics of space as will be discussed in subsection 4.2.

5. Based on step 4, it is argued that in the case of entangled systems, and prior to measurement, spatial separation and therefore distance as we conventionally conceive *do not exist*. In other words, an entangled system while being spatially extended, still exists in a single and not yet divisible (individuated) locality. This is shown to be coherent with the adjusted understanding of causality discussed in subsection 3.4.

6. It will follow that the predictions of quantum theory can be made consistent with possible experiences without giving up neither realism nor locality on the condition that we ground possible experiences on the metaphysics of individuation proposed here. Since the metaphysics of individuation does not exclude individuals, it seems to work remarkably well in cohering our understanding of both classical and quantum phenomena.

3 Individuation and its application to physical systems

3.1 Critique of Boole's conditions of possible experience

As already discussed in subsection 2.2 Boole's conditions of possible experience arise as a combination of logical propositions about properties of objects or events and the probability of observing combinations of such properties. In the discourse to this point, resolving the apparent paradox of the violation of Boole's conditions was a matter of providing physical or technical interpretations. Yet, there is another, less obvious, option: that Boole's conditions themselves are the problem. What if, contrary to our common-sense assumptions, Boole's conditions are not the proper method of universally representing possible experiences?

The notion of possible experience is quite profound; it makes explicit that in the world of phenomena, not anything goes. In other words, that in the interactions between an observer and the world certain regularities and conditions hold that make experiences appear coherent and consistent. Boole's conditions are in fact a metaphysical scheme representing a fundamental belief about how the world is and how it can be represented. Specifically, that would mean: *a*) the world can be described as a collection of objects, events and relations among them; *b*) objects and events are individuals defined by concrete sets of properties; *c*) individuals can be represented by predicates that specify their properties; and finally, *d*) individuals, their relations and modifications can be represented and reasoned about in terms of logical propositions about their properties. Aristotle's principle of the excluded middle that a property cannot both exist and not exist at the same time and there is no third option (the middle)[6], establishes the individual as a consistent and coherent concept.

In the light of the obvious violations of Boole's conditions, we criticize the universal adequacy of this metaphysical scheme. Perhaps there are phenomena that cannot be given as individuals and therefore their representation as individuals cannot be expected to yield logically consistent description of experience? In the urn example discussed in subsection 2.2, a ball cannot be wooden, red but not *wooden and red*. But even such common-sense example is warranted to work only as long as we deal with abstract representations of properties. In the actual world however, it is not free of problems and hidden assumptions and cannot be warranted to work in all cases[7].

Another remarkable example that supports our critique is the questionable individuality of a lump of sixteen cells (prior to blastulation) developing from a human fertilized egg but prior to any differentiation. Is this merely a lump of cells, a human fetus (a human person with human rights), or a tiny part of the mother's body? It is entirely unclear how to categorize the object as the same set of properties can satisfy multiple sets of propositions, each with very different and far reaching consequences. In such cases of under-determined objects we have two options: either to add an additional metaphysical presumption (e.g. the idea of spiritual conception at the moment of fertilization) that will provide the missing determination, or, we can delay our answer and wait till a natural developmental process will provide further determination.

It can be objected that in this example, the properties are given as facts and therefore this is not a real problem but a question of the interpretation of facts, but a deeper examination that will not be carried out here, can show that like in many other examples a complete separation of subsets of properties that will distinctly determine (identify)

[6]Interestingly, in eastern philosophy, there is a third option and even more than one. See for example: https://aeon.co/essays/the-logic-of-buddhist-philosophy-goes-beyond-simple-truth

[7]E.g. when the observations are made on distinct samples, conditions of lighting may affect the observed color. Also things remain wooden only within a definite temperature range that might change from sample to sample, etc.

either case is not possible. Another objection would be that at any case we can never know everything about an individual and therefore our representations are inherently partial to the actual object being represented. There are always properties which are hidden from us and these, once known, will resolve any question of determining the nature of any phenomena in a consistent and coherent manner. This is indeed the claim of all hidden variable explanations in our case. The objection tries to explain away the metaphysical problem on the basis of the incompleteness of our knowledge. Clearly, in the case of quantum entanglement this explanation fails for even if we hypothetically had all the necessary facts still the paradox persists.

In phenomena such as quantum entanglement it is no longer the case where one could argue that separability and inseparability are only a matter of interpretation of the facts. The inseparability of entangled pairs is the fact of the matter which casts a profound doubt whether the metaphysical scheme of individuals is indeed universally fit to describe natural phenomena. Apparently, quantum phenomena cannot always be represented in terms of individuals, no wonder that Boole's conditions of possible experience may be violated. A reasonable response to this critique is that our metaphysical scheme must be adjusted and extended to account for those cases where experiences are given but cannot be represented in terms of individuals. The next subsection introduces an alternative metaphysical scheme that transcends individuals.

3.2 Simondon's theory of individuation

To grasp the concept of individuation, we first need to briefly review how the metaphysical scheme based on individuals with an *a priori* given, unambiguously defined, stable identity accounts for change and the genesis (individuation) of individuals. Generally speaking, we need to identify a principle(s) and the specific initial conditions of its operation that together bring forth the individual. For example, planet earth is an individual object. To account for its genesis, astrophysicists developed a theory about the formation of planets and the necessary conditions for planets to form, e.g. the existence of a star such as the solar system. Inasmuch as this scheme makes sense, it suffers a major weakness: it only shows how individuals (planets) are formed by positing other individuals – in this case these are the identified necessary conditions that are given *a priori* and an individual guiding principle – a theory of planet formation. Clearly, in the very way we commonly think and represent the world, individuals are the primary metaphysical elements and individuation is only secondary (Weinbaum, 2015). It follows therefore that we must always assume an already fully formed individual prior to any individuation.

Gilbert Simondon was the first to criticize in depth the classical treatment of individuation and the majority of his writings (Simondon, 2005) are dedicated to developing a new philosophy of individuation. In (Simondon, 2009) he explains:

> "Individuation has not been able to be adequately thought and described because previously only one form of equilibrium was known–stable equilibrium. Metastable equilibrium was not known; being was implicitly supposed

> to be in a state of stable equilibrium. [...] Antiquity knew only instability and stability, movement and rest; they had no clear and objective idea of metastability." (see ahead)

Simondon offers a metaphysical scheme where the process of individuation is primary while individuals are secondary products. The individual is only a relatively stable phase in a dynamic *metastable process* and is always in possession of not yet actualized and not yet known potentialities of further individuation. He writes:

> "Individuation must therefore be thought of as a partial and relative resolution manifested in a system that contains latent potentials and harbors a certain incompatibility within itself, an incompatibility due at once to forces in tension as well as to the impossibility of interaction between terms of extremely disparate dimensions." (Simondon, 2009)

The process of individuation is described as the progressive determination of that which is determinable in a system but is not yet determined. Individuation is about the formation of distinctions that did not exist previously – it is about differentiation[8]. An individual therefore is not anymore a rigid unity with ultimately given properties but rather a plastic and dynamic entity in a metastable state punctuated by events of transformation. Every such event reconfigures the system and the manner by which further transformations become possible.

Metastability

The concept of metastability is central to Simondon's theory. A metastable system is a system with a number of temporary stable states where each state may display different properties. Driven by the occurrence of external perturbations, a metastable system moves among states of local stability and hence the designation that implies that no single state is ultimately stable. Furthermore, in metastable systems properties may differentiate or merge, distinct states appear and disappear and the very boundaries delineating the system may change. Metastability implies a tension between stable and unstable aspects of the individual (Combes and LaMarre, 2013).

The preindividual

In its process of individuation, an individual is preceded by a state of affairs which is yet undetermined – the *preindividual*. Deleuze, whose seminal work *Difference and Repetition* draws on many of Simondon's insights, would later describe the preindividual as "determinable but not yet determined" and individuation basically proceeds as the preindividual's "progressive determination"(Deleuze, 1994; Weinbaum, 2015). The preindividual must not be understood as a kind of ultimate disorder. It may contain partially individuated entities and principles that instruct its evolution to some extend but the combination of whom cannot fully determine the outcome. Even after an individual

[8] In its wider sense individuation speaks about both the formation and dissolution of distinctions.

has reached a relatively stable state or formation, the preindividual is not necessarily exhausted and keeps on persisting in the individuated system as a source of inherent instability. It is the presence of the preindividual that allows subsequent individuation.

The unity characteristic of fully individuated beings (i.e. identities) and warranted by the application of the principle of the excluded middle, cannot be applied anymore to the preindividual. The preindividual is that intrinsic aspect of the individual that goes beyond its unity and identity. It is important to emphasize here the metaphysical sense in which this is said: *individuals are not only more than what they appear to be (in our representations), but also more than what they actually are.* Precisely here lays the paradigmatic shift in the metaphysical scheme from *being* (individuals) to *becoming* (individuation).

Simondon also emphasizes that relations between individuals undergo individuation too: "A relation does not spring up between two terms that are already separate individuals, rather, it is an aspect of the *internal resonance of a system of individuation.* It forms a part of a wider system." (Simondon, 1992, p. 306). Furthermore, individuation never brings to light an individual in a vacuum but rather an individual-milieu dyad. This dyad contains both a system of distinctions and a system of relations. The individual and its milieu reciprocally determine each other as they develop as a system wider than any individual.

Transduction

Transduction is a technical term Simondon is using to designate the abstract mechanism of individuation. The term captures some of the most innovative (and important to our case) characteristics of individuation. Understanding the term cannot make use of classical logic and procedural descriptions because they require the usage of concepts and relationships among concepts that only apply to the products of the operation of individuation (Simondon, 2009, p. 10). Transduction comes to designate therefore a metaphysical scheme that is constructed from a generative point of view that precedes any *a priori* given individuals. In Simondon's words:

> One could, without a doubt, affirm that transduction cannot be presented as a model of logical procedure having the value of a proof. Indeed, we do not wish to say that transduction is a logical procedure in the current sense of the term; it is a mental process, and even more than a process, *it is a functioning of the mind that discovers* [emphasis added]. This functioning consists of following being in its genesis, in carrying out the genesis of thought at the same time as the genesis of the object. (ibid., p. 11).

To further highlight the metaphysical nature of transduction, Simondon argues that transduction cannot be captured by the logical operations of either deduction or induction. Transduction is not deductive since it does not posit a given principle(s) or pattern(s) external to the process that can instruct the resolution of the present situation. Deduction can only highlight that which is already given by fully individuated knowledge. Transduction 'discovers', or rather brings forth, elements and relations that did not exist before. Furthermore, transduction is not inductive in the sense that it does not extract or highlight the properties or patterns common to the unique and not yet compatible elements of the individuating process. These usually serve as the basis to inductive reasoning about the process, thereby eliminating what is unique to the elements. Instead, "[T]ransduction is, on the contrary, a discovery of dimensions of which the system puts into communication [...] each of its terms, and in such a way that the complete reality of each of the terms of the domain can come to order itself without loss, without reduction, in the newly discovered structures." (Simondon, 2009, p. 12).

Application to quantum phenomena

In brief, quantum systems prior to measurement are not fully individuated. The measurement of a complementary property in a quantum entangled system is an *individuating event* with respect to the property being measured[9] in the sense that it determines something that was not determined before, it brings forth a distinction, a differentiation. Measurement does not merely change the state of our knowledge about reality. It actually changes the state of both *knowledge and reality.* As we have seen, these, according to Simondon, individuate together (Combes and LaMarre, 2013). In this sense, measurement in quantum systems actuates the transduction mechanism.

Describing measurement as an individuating event elegantly fits the fact that complementary properties cannot be simultaneously measured and require distinct samples (see subsection 2.2). Individuation takes place when some property which was not determined, gets determined. But clearly a property cannot be determined twice from the very same predetermined state. Individuating events are ultimately unique, hence can each be sampled only once.

Interestingly, the concept superposition of states can be understood as a projection of individuated properties post measurement back to the non-individuated state of affairs prior to measurement. The wave functions being superimposed, are always in conjunction to an arbitrarily selected specific measurement (e.g. measuring spin or polarization in direction x), they have no meaning independent of the measurement settings. This quantum wave modality illustrates best a system in the course of individuation. Even when an individuating event takes place, the system becomes individuated and yields a concrete and consistent outcome only in the context of that same event (measurement). But since every arbitrary measurement that follows potentially changes the reality of the system, the preindividual intrinsic to the system is never exhausted.

A quantum system is therefore an exemplar of a metastable individuating system. All its individual products are always given only in relation to the latest individuation event. The probabilities associated with superimposed states should not be interpreted as if they reflect frequencies of already defined properties (like in the urn example). They

[9]Generally, a measurement is not always an individuating event. It depends whether the actions involved in the measurement produce for the measured system a perturbation strong enough as to move it from its current stability towards another stability. But it can be said that in every individuation event, certain determinations must take place and therefore it can always be understood as measurement in the broad sense.

rather indicate a statistical regularity of how the undifferentiated state might evolve and this depends of course on what is already known and what will be measured next.

In summary, Simondon's theory presents a paradigm shift in the way we can relate to the quantum world: from a view based on individual entities, to a view based on ontogenetic processes that bring forth individual entities. The implications of this shift on understanding quantum phenomena are discussed next.

3.3 Individuation and realism

The most counter intuitive and intriguing behavior of entangled systems is the case where separability is challenged. Separability means that spatially separate systems posses separate real states (real is said here in the physical sense). Howard, (1985) strongly emphasizes the profound significance of separability for physics:

> [I]t should be understood that the separability of two systems is not the same thing as the absence of an interaction between them, nor is the presence of an interaction the mark of their non-separability. The separability principle operates on a more basic level as, in effect, a principle of individuation for physical systems, a principle whereby we determine whether in a given situation we have only one system or two. If two systems are not separable, then there can be no interaction between them, because they are not really two systems at all.

Quantum entangled systems definitely do not follow this principle. For example, a pair of particles[10] having their spins entangled form a system which is not fully individuated and therefore inseparable. Distinct individual spins do not exist for each of the particles[11] constituting the system; there is only an internally correlated joint spin state for the whole system. Of course inseparability is reflected in the mathematical formalism used to represent such states. It uses the principle of superposition borrowed from the fact that individual particles behave also as waves that can be superimposed and yields an expression that provably cannot be decomposed into separate expressions for each particle.

Einstein's concerns regarding quantum theory were centered on the fact that in its very formalism it denies the principle of separability. For him, separability seemed to be the essence of realism:

> However, if one renounces the assumption that what is present in different parts of space has an independent, real existence, then I do not at all see what physics is supposed to describe. For what is thought to be a system is, after all, just conventional, and I do not see how one is supposed to divide up the world objectively so that one can make statements about the parts. (ibid., p. 191)

[10] Generally, more than two particles can be entangled and form systems where individuation can take many paths and can become intractably complex.

[11] We can call them particles because they may still possess other properties such as mass or charge that partially identifies them as distinct entities.

Einstein was worried that without separability, there will be no way to objectively distinguish between physical systems and this will inevitably leave us only with subjective, observer-dependent (and arbitrary) interpretation of what constitutes a physical system. It is also clear that Boole's conditions of possible experience are exactly those conditions under which the "statements about the parts" mentioned by Einstein can be safely made and tested. They are constructed in a manner that ensures the separability of observed systems. This is why we cannot expect entangled quantum systems to follow Boole's conditions because these require all properties to be fully differentiated and separable (e.g., in the urn example, woodenness should never depend on redness etc.).

It is here that Simondon's metaphysical scheme becomes relevant to the problems discussed in this paper. What Simondon's scheme allows is to metaphysically accommodate individuating non-separable systems. This necessarily changes the whole view about reality (not only quantum reality): individuals occupy only a small and secondary part of reality. Entities in the course of individuation with yet undifferentiated properties are the rule rather than the exception. It is only an epistemological convention (and convenience) that we approximate such entities by representative individuals. Such approximation allows to represent phenomena in terms of discrete predicates and logical propositions. But reality is far from being fully captured by such representations, and apparently there are vastly more possible experiences than those allowed by Boole's conditions that apply only to individuals.

We can contrast now *hard realism* – a description of phenomena in terms of fully formed individuals with *soft realism* – a much broader description that includes partially formed individuals with as yet undifferentiated properties[12]. When applied to quantum phenomena, with soft realism, we depart from the conventional realist position which is hard realism but we do not have to go as far as the non-realist position that denies altogether the existence of measurement-independent properties either. To assert that measurement is instrumental to the individuation of certain systems is to affirm that reality is not something which is either *a priori* given or does not exist at all but rather that reality is in a continuous process of individuation (ontogeny).

We already know that representations based on hard realism are problematic. The violation of Boole's conditions is clear enough evidence for that. But does soft realism help us to achieve a more consistent representation? It seems that it does. Based on Simondon's metaphysical scheme, soft realism allows a novel kind of possible experience – a partially individuated entity as exemplified by entangled systems. For such systems, the so called violations predicted by the theory and validated by experiment are not violations at all. Quantum theory predicts with unprecedented success the outcome of measurements performed on systems that are only partially individuated. The troublesome correlations discussed in section 2 positively indicate the inseparability of the entangled system, but now we have a metaphysical scheme that accommodates this fact. Physics remains intact and our understanding of the world gains a profound refinement and much needed consistency of representation. This view is supported by Howard as well:

[12]The term *partial identity* can be synonymously applied.

> [...] We should make the existence of quantum correlations a criterion of non-separability. After all, if it were not for the existence of these peculiar correlations which violate the Bell inequality, the separability principle would not be threatened. In other words, what I suggest is that instead of taking the quantum correlations as a puzzle needing explanation, we should make these correlations themselves the explanation [...] (Howard, 1985, p. 198)

What Howard was seriously missing is the metaphysical backup provided by Simondon's theory. Without it, his suggestion seems to be merely an arbitrary choice of convenience. But it makes much sense in the light of the metaphysical scheme of individuation: spatial separation is not enough as the ultimate criterion of separability. We will discuss this further in section 4.

3.4 Individuation and conditions of possible causal explanation

Individuation is an abstract process that does not provide the specific physical mechanism of the actual determinations and differentiations that take place in its course. For that matter it does not even provide a hint as to what kind of explanations one can expect. Quantum theory is a theory of statistical regularities. Conventional classical thinking seeks to explain statistical regularities as originating from actual distributions of properties in a hypothetical population of individuals with *a priori* defined identities. But this approach is rooted in hard realism and does not offer a viable resolution of the paradox. From the perspective of soft realism, quantum theory describes systems undergoing individuation. These do not 'hide' mysterious individual elements (hidden variables) on which causative explanations can be anchored. Does soft realism offer an alternative to conventional causative explanations?

We have already seen in subsection 2.3 that abandoning realism might be a way out. Pitowsky makes it clear that the issue at stake is not so much giving up realism but the idea of giving up causality – more precisely the principle that no event happens without a cause. Pitowsky's suggestion that the statistical regularities in the case of quantum entanglement have no causal explanation is not as speculative and dismissive of causation as it might seem at first sight. He writes: "There is no 'deeper reality' which causes them [the statistical regularities] to occur; the phenomena themselves are their deepest explanation." (Pitowsky, 1994, p. 118). If we carefully reexamine this quote in the light of the inseparability of entangled systems we find a deeper sense. Given two entangled particles A and B, how can we describe the effect of a measurement made on A on the measurement made on B if the particles are not separable? If A and B are one and not two distinct systems, in what sense can one produce effects on the other? Is it not the case that both cause and effect are internal to a single non-decomposable whole and this is the best one can do in describing what is going on without dismissing causality altogether?

Thinking in terms of individuals necessitates that in order for one entity to act upon another one and cause an effect, they need to be separate and external to each other. Even feedback systems that when observed from outside can be seen as if acting upon themselves, can always be represented as having internal structure that separates input subsystems from output subsystems. In this sense, a causative relation is always a relation of externality – external to the related elements. Thinking in terms of individuation is entirely different. A system in the course of individuation is in a state where elements are not entirely differentiated yet not entirely homogeneous and indistinct either. In such systems a causative relation can be understood only as a relation of internality where both the acting and acted upon elements are not entirely distinct; their relation therefore is internal to them[13]. And since they are not entirely distinct one cannot even discern the direction of action – which of the elements is the acting and which is the affected[14]. In other words, causes and their effects are confused. It seems that this state of affairs can receive only an approximate description using a language optimally fitted to mostly describe relations of externality. It can be said however that the causation relation itself is individuating and not entirely distinct (see above p. 13 on the preindividual).

The traditional concept of causality involved two requirements: spatio-temporal contiguity and regularity (similar causes are followed by similar effects) (Ben-Menahem, 1989). The core of Hume's skepticism regarding causality was that the causing agent and the affected agent are ultimately distinct. There is always something that must come between them to mediate action and this necessity, Hume argued, cannot be logically established; it is only empirically established. In other words, effects cannot be logically derived from causes only inferred. In individuating systems we face a different and in some sense an opposite problem where the causing agent and the affected agent though spatially separate are not entirely distinct. Contiguity in this case attains a sense which is other than the traditional spatio-temporal relation; it is contiguity defined in terms of an additional property dimension. If this dimension represents for example the direction of spin, there is only a single (yet arbitrary) value representing the direction of both particles. The particles therefore are found contiguous in this dimension. In contrast to being a mere empirical fact obtained by observation, it is an ontological and logically established contiguity. Nowhere and in no case can one intervene to change the property of one particle, without affecting a change in the other. If two things cannot be separated, they are necessarily contiguous in some very significant sense. It can be said, therefore, that the relation of entanglement is stronger than the traditional causal relation; the mutual effect is more profound. It is not mere regularity that we observe in the behaviors of entangled particles, it is logical necessity arising from their non-separability.

Furthermore, there is neither metaphysical nor logical reason to privilege one physical property (spatial separation) over another (non-separable spin states) in judging the distinctiveness of elements of an entangled system. Hence, 'action over distance' fails

[13]The idea of the difference between relations of externality (that require the separation of elements) and relations of internality (that require continuity and interpenetration of elements) originated in the works of another eminent philosopher of beginning of the 20th century Henri Bergson (Bergson, 2001, p. 227) (see also: (Deleuze, 1991)). Bergson's work predates Simondon's and deeply inspired his philosophy of individuation. His work will be further discussed in section 4

[14]With relativistic considerations taken into account, the measurement on either particle can precede the measurement on the other depending on the frame of reference of the observer. In as far as causes precede effects the ambiguity of the situation is very real.

to describe what is going on in entangled systems. Clearly the relation of entanglement involves both more than and less than what we conventionally conceive in the concept of action (causing something to happen). The following section will continue to further scrutinize the application of the notion of spatial separation to entangled systems.

The position of soft realism towards causality again takes advantage of the concept of individuation to establish that physical interactions can be more subtle and complex as to neatly fit into or be excluded from the traditional category of causal relations. Individuating relations are understood as relations of internality rather than relations of externality. Measurement as an individuating event, externalizes (exposes to the external observer) a relation that was internal up to that point. Consequently, the states of both knowledge and reality have thus changed.

To this point, the discussion focused on a single system of entangled particles. How does this analysis reflect on explaining the actual statistical regularities predicted by Quantum theory? Are we still stuck in a position that forces us to choose between a paradoxical explanation (non-local effects) and no explanation at all (non-realism)? Is there an alternative supported by the analysis above? There is no doubt that the statistical results of EPR type experiments are reflecting the behavior of a population of entangled systems. We can now see that the paradox arises because the population is of individuating entities and not of individuals. Since measurements are individuating events, and no single entity can be individuated more than once, complementary properties must then be measured on distinct samples of the population. This wouldn't normally pose a problem if not for the fact that the population prior to measurement and the population post measurement are not the same populations. *There is a metaphysical difference between the members of the two populations, they are not of the same kind.* Whereas the first is of individuating pairs, the second is of pairs of individuals. The paradox arises therefore when we expect the first to behave as the second would, as if they were of one and the same kind. Accepting this difference brings us back to Pitowski's words: "[T]he phenomena themselves are their deepest explanation." If individuation is a fundamental state of reality there is no need to seek for a deeper explanatory element. It is entanglement itself that explains the correlations discovered in experiment.

In summary, while conventional causative relation cannot be said to exist between the particles of a single entangled pair and needs to be replaced by the more refined understanding of their relation as suggested above, accepting entangled systems as individuating instead of individuals is enough to cause the observed statistical regularities. It is simply not an *a priori* distribution but how individuation works. For any sample of the population, the fact of having belonged to a single undifferentiated entity leaves a trace in the behavior of each and every pair that measurement brings forth.

4 The individuation of space

4.1 Rethinking locality and its role in individuation

We have seen the criticality and problematics of separability to the understanding of entangled systems and to the notion of realism. The definition of separability as discussed in subsection 3.3 requires that spatially distinct system must have separate real physical states. As much as the definition seems simple and straight forward, a closer examination exposes an unexpected complication. If we understand spatial separation to be a purely physical property, there is no reason (as already mentioned) to privilege it over other physical properties in judging whether two physical systems are separate or not. Perhaps it is only a perceptual habit to see spatial separation as some kind of a primal criterion? Perhaps a pair of entangled particles is a single system spatially extended but spatial separation is only secondary in significance? More relevantly to our issue, we must consider systems where elements are both separable and not. If, on the other hand space is more than just a pure physical property; that it somehow transcends the purely physical, than on account of such transcendence, its special privileged status might be justified. According to Kant, space indeed enjoys a special status:

> Space is not an empirical concept which has been derived from outer experiences. For in order that certain sensations be referred to something outside me (that is, to something in another region of space from that in which I find myself), and similarly in order that I may be able to represent them as outside and alongside one another, and accordingly as not only different but as in different places, the representation of space must already underlie them. [...] Therefore, the representation of space cannot be obtained through experience from the relations of outer appearance; this outer experience is itself possible at all only through that representation. [...] Space is a necessary a priori representation that underlies all outer intuitions. One can never forge a representation of the absence of space, though one can quite well think that no things are to be met within it. It must therefore be regarded as the condition of the possibility of appearances, and not as a determination dependent upon them, and it is an a priori representation that necessarily underlies outer appearances. (Kant, Guyer, and Wood, 1998)

In other words, the separability in space, which comes *a priori* to any representation is a sufficient condition that systems separated by space alone are already *physically separated* in any possible experience and therefore must also posses separable real states. Janiak, (2012) makes an interesting distinction between a realist relationalism and realist absolutism in regards to space. Whilst the first is the position that space is the order of possible relations among objects, the latter is the position that space is an object-independent framework for object relations. From the perspective of the first position, it is conceivable that spatial separation might depend on other relations between objects (e.g. their quantum states). It might be the case that separation and conventional distance are not one and the same and not any conventional distance automatically reflects a separation as this may depend on other non-spatial relations between the systems under consideration. The second position that claims an object-independent status to space, seems however to be the one consistent with Einstein's views. From the standpoint of special relativity, signals can move through space-time only in a limited speed. Spatial separation means therefore a limit on the communication between two physical systems and this limit was in Einstein's eyes a fundamental one because this very communication is *a priori* intrinsic to *any relation* and any physical interaction between two physical entities.

Yet it is clear that entangled systems that are spatially separated do not communicate in a manner that violates special relativity in any respect. They do however *relate* in a special manner as if no spatial separation exists between them. I argue here that Einstein's concern regarding quantum phenomena arose from his realist absolutism position which is a metaphysical one[15]. But there is no compelling point to hold to this position because it is not the only one that is consistent with empirical data. The alternative realist relationalism which is intrinsic to soft realism is consistent with existing theory and all empirical data and in the case of the EPR paradox invites to reexamine the deeper meaning of locality in entangled systems and whether the principle of locality is indeed violated. I will argue that based on the metaphysical scheme of individuation, in the case of entangled objects, space as the order of possible relations among objects is itself subject to individuation inasmuch as the relations it orders themselves individuate. This will lead us to consider an additional metaphysical adjustment having to do with the concept of locality. The argument is based on the metaphysics of space developed by Bergson which is briefly presented next.

4.2 Bergson's metaphysics of space

Bergson's metaphysics of time and space is very rich and complex. It is not within the scope of this paper to provide the wider context of Bergson's writings[16] which are necessary for the deeper grasp of his metaphysical method. Here we try to extract in brief only the few points which are relevant to the topic at hand. At the basis of Bergson's thought about the metaphysical nature of space is a combination of the following three philosophical observations.

Distinction between space and extensity

In (Bergson, 2001) we find the following:

> We must thus distinguish between the perception of extensity and the conception of space: they are no doubt implied in one another, but, the higher we rise in the scale of intelligent beings, the more clearly do we meet with the independent idea of a homogeneous space:

The distinction is a subtle one: while extensity is an actual objective manifestation of physical objects, space, Bergson argues, is conceptual and involves the mind of an

[15] It might sound strange that Einstein who conceived relativity theory held a realist absolutist position. But the sense of absolutism here is the claim that spatio-temporal relations between objects are the basis to any other relation and antecedent to any other relation. 'Realist absolutist' is just another name to a position that privileges spatio-temporal distinctions to any other distinction.

[16] Especially "Time and Free Will" and "Duration and Simultaneity" – Bergson's investigation of relativity theory (Bergson, 1965, 2001).

observer. The exact nature of the concept and its function will become clear in the following.

Homogeneity of space

Furthermore, Bergson contrasts the qualitative heterogeneity of our conscious experience with the homogeneity of space:

> What we must say is that we have to do with two different kinds of reality, the one heterogeneous, that of sensible qualities, the other homogeneous, namely space. This latter, clearly conceived by the human intellect, enables us to use clean-cut distinctions, to count, to abstract, and perhaps also to speak. (Bergson, 2001, p. 97)

According to Bergson, the reality of experience is a continuum of heterogeneous qualitative change that does not admit any intrinsic distinction or separation. Only by projecting this continuum onto space, can one start making distinctions and separations:

> [S]pace is what enables us to distinguish a number of identical and simultaneous sensations from one another; it is thus a principle of differentiation other than that of qualitative differentiation, and consequently it is a reality with no quality. (ibid., p. 95)

The homogeneity of space is exactly this: being devoid of quality. As such, it is always external to anything with quality. Therefore, space is the kind of reality that enables relations of externality. Without applying the concept of space one can only conceive of relations of internality where no separation can be made[17].

Space is infinitely divisible

The third and most important observation is brought in the following quote from Matter and Memory (Bergson, 1991, p. 206): "Abstract space is, indeed, at bottom, nothing but the mental diagram of infinite divisibility." Bergson further explains:

> Such is the primary and the most apparent operation of the perceiving mind: it marks out divisions in the continuity of the extended, simply following the suggestions of our requirement and the needs of practical life. But,

[17] This is quite easy to see: if something having a quality A changes into having a quality B, what happens at the limit between A and B? The limit must either consists of both A and B or neither, for any other options (i.e. either A or B) is inconsistent with it being a limit. If the limit consists of both A and B it is impossible to fully separate A from B because at least at their limit they are inseparable. The option that the limit consists of neither A nor B is indeed the only one left. Now suppose the limit consists of having another quality C different than both A and B, then we must ask recursively the same questions about the limit where A changes to C etc. We are left therefore with the option that C is the absence of any quality. Only in such case we can claim that A and B are indeed mutually external to one another and entirely separate. C is Bergson's conception of space. It is in fact the Aristotelian middle being excluded.

> in order to divide the real in this manner, we must first persuade ourselves that the real is divisible at will. Consequently we must throw beneath the continuity of sensible qualities, that is to say, beneath concrete extensity, a network, of which the meshes may be altered to any shape whatsoever and become as small as we please: this substratum which is merely conceived, this wholly ideal diagram of arbitrary and infinite divisibility, is homogeneous space. (Bergson, 1991, pp. 209-210)

Space and individuation

Bergson's thought brings forth interesting points relevant to our investigation. Understanding space as a mental diagram of divisibility and distinguishing it from extensity means that physical extensity does not automatically imply divisibility. In other words, physical objects and systems may be extended without being divisible. Moreover, divisibility is not fundamental; continuity and non-separation are the fundamental conditions of the real according to Bergson. Divisibility which is necessary for separability is not intrinsic to the real[18]; it requires an extra "ideal diagram" to be casted beneath the real. This is to say that spatial separation based only on extensity *is not* metaphysically privileged (or *a priori* warranted) over other physical qualities. In fact, the very idea of pure spatial separability that appears to be deeply intuitive is put into question.

One may go as far as concluding that Bergson's concept of space and divisibility is fundamentally subjective and requires the intervention of the mind of an observer. But Bergson's idea is more subtle: divisibility and separation may still be observer independent thus sustaining their realist status. However, one cannot distinguish between two objects *only on account of the absence of a quality.* Space can be thrown beneath a continuity of sensible qualities, but if these are missing there is nothing to divide or separate. In other words, physical entities, whether observed or not, are not and cannot be separated only on account of purely geometrical relations.

From here it is clear how this conceptualization of space is consistent with the realist relationalism position mentioned in the previous subsection: space as the order of *possible relations* among objects. In as far as physical entities can be separated at all, and since they cannot be separated only on account of an absence of quality (i.e. only spatial separation), it follows that the condition of their separation is that their possible relations must be based on concrete qualities/properties. There must be something rather than nothing which space might divide. But if that 'something', that physical entity, is spatially extended but nevertheless intrinsically indivisible, space cannot possibly make it divisible though our habitual intuitions may tell us otherwise. Only in cases where physical entities are divisible and separable on account of other qualities or properties, the idea of space applies to represent their distinction. At the beginning of subsection 3.3 we defined and discussed the concept of separability (i.e. spatial separation implies separation in state) and its importance. It is clear now that the concept is based on

[18] Remarkably, the concept of distance as reflecting spatial separation is applicable therefore only on account of space being homogeneous, devoid of quality and divisible. Without these, we can speak distance only as some conventional measure of extensity.

presuming the primacy of spatial separation over all other quality based distinctions. This primacy, we find, is merely a feature of a particular metaphysical scheme. I have presented here an alternative metaphysics of space without this particular feature. I also argue that there is no reasonable basis for such primacy. The bottom line of this whole discussion is that in our proposed metaphysical scheme, spatial separation *does not and cannot imply* separation in state on its own; on the contrary, separation in state *is a necessary condition* to spatial separation.

From the perspective of the metaphysics of individuation, there is no *a priori* condition of entities being divisible or not. In other words, divisibility (i.e. separability) itself can individuate; which means that it is possible that a certain physical entity is spatially extended but not divisible will individuate and bring forth two or more spatially separate entities that did not exist before[19]. This very possibility of the individuation of separability as a consequence of the individuation of other physical states and relations is the additional adjustment we need to accommodate following the metaphysical scheme of individuation.

4.3 Locality in entangled systems

Let us now return to the case of a system constituted by two entangled physical entities in an EPR kind of setup. Following our new metaphysical scheme, though the system is spatially extended, we cannot take for granted anymore that the entangled entities involved are spatially separated. Considering *only* the entangled property, there is no way we can assign an independent state to any of the entities constituting the system and this implies that space as a principle of differentiation is not applicable. In other words, *there is no meaningful way to speak about locality or distance within the entangled system.* This may seem quite incredible and counter intuitive but this is only because our profound habit of perceiving and thinking in terms of sharply defined individuals and also that anything spatially extended is also spatially divisible.

We already argued in subsection 3.4 that the spooky action at a distance that has become emblematic of entangled systems is not an action in the conventional sense of the word. We now complement that argument: it might well be a spooky action but *there is no distance that reflects distinct localities*! It is by now a well established fact that entangled systems behave the same no matter how far they are spatially extended. What we conventionally measure as a distance between the entangled entities reflects extension but the separation it seems to reflect is only a feature of our conditioned imagination. The physical entities involved do not behave in any manner as to indicate that there is any spatial separation derived from the measured distance between them.

Reality, of course, is not that simple. Each of the entities constituting an entangled system may (and often do) possess in addition to the entangled property other properties such as mass and charge that are independent. In such cases which are the majority, the spatial separation between the entities is not fully individuated. The entities are *both spatially separable and inseparable* depending on which of their properties is under

[19] Also the other direction is possible: where two or more spatially separate entities merge into a single undifferentiated spatially extended entity.

consideration. Such state of affairs which is contradictory according to the metaphysical scheme of individuals, is entirely consistent within the metaphysical scheme of individuation.

In summary, locality in entangled systems is not an *a priori* given but individuating. Prior to measurement, it is not yet differentiated. The system is spatially extended but not spatially divisible. A measurement of the entangled property is an individuating event; it brings about a differentiation in state and consequently spatial separation between the once entangled entities.

Inasmuch as individuation allows us to think in terms of soft realism, it allows us to think in terms of soft locality too. Hard locality is based on the assumption that spatial separability is a given and therefore the location of a physical entity in relation to other such entities can always be singled out. Soft locality does not assume that; instead, it accepts that spatial separability is not a given and is not applicable in the absence of other separating physical properties. Contrary to that, it is conditioned on the presence of entities with independent properties or states. If physical entities do not possess such properties they cannot be said to be spatially separated even though they together may constitute a spatially extended system. Soft locality does not give up locality but distinguishes between cases where space as a differentiating principle is applicable and cases where it is not. But most remarkably, soft realism accepts locality as an individuating feature of physical systems.

5 Conclusion

The problematics presented by the EPR paradox have nothing to do with the facts of physics and the predictions of quantum theory. We have clarified that the problem is first and foremost epistemological. We expect our knowledge of reality to be coherent and consistent across all phenomena at all scales, but the observed violations of Boole's conditions of possible experience in the behavior of quantum entangled systems clearly put in question such coherency.

Along almost a century of discourse about how to resolve the paradoxical findings involved in quantum phenomena, three different ideas played a major role namely: *a*) the incompleteness of quantum theory, *b*) accepting non-locality, and *c*) accepting non-realism. Though we can never assure the completeness of the theory, the latest empirical findings prove that even if quantum theory is incomplete, either non-realism or non-locality are still necessary to resolve the apparent paradox. Clearly, neither of these resolutions coexists comfortably with how we understand the rest of reality. The more we try to cohere them the more disturbing they become.

In this paper I propose a different approach to the resolution of the paradox. It is argued that the paradox is rooted in the metaphysical scheme that is supposed to provide a foundation to our knowledge of reality (including also our intuitions). This metaphysical scheme is based on the idea that reality is given in terms of individuals. It is from this idea that Boole's conditions of possible experience are derived. I argue that the violations of Boole's conditions do not indicate an incompleteness of quantum theory, nor a lack of understanding of its meaning. What they do indicate is a failure to accommodate certain phenomena within the metaphysical scheme that we use. In other words, *there are* actual experiences that do not comply with Boole's conditions which means that they cannot be described within a metaphysical scheme based only on individuals. The solution to the paradox would therefore be achieved by modifying and expanding the metaphysical scheme that we use as a basis of our knowledge of reality into one that can accommodate the actual experiences involved in quantum phenomena.

Based on the works of Simondon and Bergson, I have proposed here an alternative metaphysical scheme which is based on the idea that reality is given in terms of processes of continuous individuation and where individuals are only impermanent products of such processes. I have shown that within such a scheme our notion of realism changes from hard realism to soft realism and also, as space itself individuates, our notion of locality changes from hard locality to soft locality. I have further shown that individuation as a metaphysical concept and the consequent adjustment thus made to both realism and locality, allows us a coherent description of quantum entanglement within a wider epistemological framework and provides an elegant resolution of the paradox.

As a concluding note I would like to briefly reflect on the method underlying this paper. Though the discourse in this paper focused on the EPR paradox, most of the arguments that were brought here and the application of the metaphysical scheme of individuation are relevant and generally applicable to a very wide spectrum of phenomena. It is my belief that metaphysics has an important if not critical role in the progress of scientific knowledge and our general understanding of reality. Metaphysics systematizes a set of fundamental assumptions about reality. Surely, it does not precede reality but it does precede the manner by which we perceive and conceptualize our perceptions into representations that constitute a coherent and reliable body of knowledge. As such, and because it is so fundamental it tends to hide from the scrutinizing eye and its precepts are often taken for an unassailable truths never to be questioned. There is only one remedy to this situation: metaphysics must not be isolated from science and science must not be isolated from metaphysics, one must keep the other in progressive check as both are undergoing individuation. Together they form a vital exchange, a dance that brings forth knowledge and the elegance of coherence.

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Part IV

Conclusion

Chapter 15

Precis

It is inevitable that cognition is given in terms of objects and thinking in terms of concepts. It is inevitable that all knowledge is representation and in all these, difference is subordinated to identity. More fundamentally, though we experience that everything is in flux, it seems inevitable that existence must somehow be rooted in a ground of permanence. The perennial difficulty that is the source of this object-oriented conception of the world is in accepting change (impermanence) as the primal ground and existence as merely the resistance to change of that which is fundamentally rooted in change. This work challenges these apparent givens and presents an attempt to expand the horizons of thought and being beyond the limits they spell. It addresses the difficulty by providing an alternative view of existence as an unfolding drama[1] – an ongoing evolution manifesting in the play between change and its boundaries. This alternative view does not come to negate anything. Inasmuch as pointing to an embryonic state does not negate the fully developed organism, so the view developed in this work does not negate objects and the object-oriented conception of the world. It claims, however, that everything born to exist was once in an embryonic unformed state and this state is latent in everything, no matter how final or arrested its actual development may seem. The following is a conclusive overview of how this expansion of horizons is achieved.

15.1 From Difference to Ideas

The Image of Thought

The first step, carried out in chapter 2, frames and clarifies the philosophical problem of how thought begins. It highlights a complex of presuppositions underlying thought that is naturally and commonly given to all thinking subjects. Deleuze claims that all philosophies share a common pre-philosophical image – the image of thought, that was never questioned. It finds perhaps its boldest expression in Descartes' 'Cogito'. In a nutshell, the image is *a*) that thought is a representation of a world already present, *b*) that the subject of thought is thus constructed in a manner which is fit to produce thought as a reliable representation of the object of thought

[1]Etymologically the word drama is derived from ancient Greek $\delta\rho\alpha\omega$ which means to act, to play and also to achieve.

that belongs to the world, *c*) that there is an *a priori* affinity of thought to truth which is grounded in this fitness, and finally *d*) that underlying the above suppositions is the supposition of identity as a primary element and with it an object-oriented conception.

Thought Sans Image

Following a critique of these suppositions, the problem that emerges is the problem of thought sans image: is there a thought that comes before the image and is not supported by it? This problem becomes the point of departure and the leading direction of an exploration that seeks to break with object-oriented metaphysics, which is rooted in the image of thought. Prior to whatever arises as representation, prior even to subject-object distinction, there is an 'encounter' that forces thought to become. It is an encounter of a metaphysical nature but it also has an actual expression. In the introduction it was already termed 'the event of cognition' (see page 5 and 5.4.2). It is the crossing of a critical threshold; not only a threshold of thought but a threshold of being sensed – a threshold of existence. In thought sans image we seek the genesis of thought and, as is clarified later, the becoming that precedes being.

Bergson's Two Dimensions of Mental Activity

Thought sans image is next addressed in the light of Bergson's work. Chapter 3 highlights two ideas prominent in Bergson's philosophy which are indispensable to this work. The first idea is that there are two dimensions of mental activity. The first is thought in space, which is the source of analytic knowledge and symbolic representation and is very much consonant with thought based on the image of thought discussed in chapter 2. The second is thought in duration – a holistic kind of thought, indivisible and non-representable – the one experienced via intuition as the uninterrupted stream of consciousness. Duration is clearly a dimension of thought sans image[2]. Bergson's development of the concept into a rich conceptual framework is successful in lending thought sans image the tangibility it was initially missing yet without enclosing it inside another image.

Virtual and Actual

In Bergson's work, thought in space is quantitative, and its objects are homogeneous, immobile, distinct and divisible. Thought in duration is qualitative. It is heterogeneous, mobile, non-distinct and indivisible. There are no distinct forms but rather an ongoing formative process. Three major pairs of concepts distinguish thought sans image from thought as representation. These are relations of interiority in contrast

[2]The concept duration evolved throughout Bergson's lifetime. The earlier versions addressed mainly the aspect of representation in the image of thought while later versions addressed other aspects as well.

to relations of exteriority, qualitative multiplicity in contrast to quantitative multiplicity and most significantly virtual existence in contrast to actual existence. Actual existence is all about form and action but beneath the surface drawn by forms and actions exists an immeasurable depth of the not yet formed and not yet actual. And though the virtual is inaccessible without first becoming a distinct form or action, i.e., rising to the surface, it is nevertheless that which forces thought and being to become and as Deleuze later reflects: "It is not the given but that by which the given is given".

Metaphysical Self-organization

Bergson's second prominent idea is raising the two mental dimensions of thought – duration and space, the virtual and actual, to a status of metaphysical dimensions. It is in this move that thought sans image starts to gain its freedom from an *a priori* image of a thinker. The shift from the mental-psychological to the metaphysical is difficult. It removes the thinking subject from its instrumental role in the discourse, which leaves a few explanatory gaps that are discussed in some detail. At this point the hypothesis of metaphysical self-organization is asserted in an attempt to cohere the several options of filling the said gaps. Rooted in Bergsonian philosophy, it extends it in order to explain how the universal metaphysical continuum conceived by Bergson spontaneously manifests objects states and relations with various degrees of relative mobility and immobility. Metaphysical self-organization is a tendency engendering a productive process that brings forth an actual world as its product. In simplified terms it amounts to the proposition that mobility and immobility endure in each other and this is a sufficient condition for order to arise out of (and dissolve into) non-order. Remarkably, the hypothesis is minimalistic in the sense that it presumes only change, which in the Bergsonian terminology is a combination of mobility and heterogeneity.

Deleuze's Virtual Dimension

The next step in the development of thought sans image as a formative process leads to Deleuze's metaphysical theory. Bergson's metaphysics was by comparison only the schematics for Deleuze's metaphysical architecture. It contained already many of the insights but lacked a detailed conceptual structure. Deleuze's work accomplishes Bergson's departure from an identity-based metaphysics by replacing identity with difference as the metaphysical element. He goes further than Bergson in addressing sense and thought beyond the human condition and finally highlights thought (the expression of Ideas) as a process of creation rather than the discovery of what already exists. The foundational concepts in Deleuze's metaphysical theory are difference and repetition. Difference is the element of thought sans image and repetition is the formative element that is involved in the individuation of identities as secondary elements.

Difference – Unilateral Determination

While conventionally difference is always related to things that are already defined, i.e., identities, Deleuze's concept of difference liberates it from any identity that precedes it. The novel concept of difference is deceptively simple. It is a determination that takes the form of unilateral distinction: something which distinguishes itself – and yet that from which it distinguishes itself does not distinguish itself from it. Differences appear all at once as a vast plane where distinctions, being unilateral, are never complete. Differences differ but remain interconnected.

Difference and Univocity

In order to establish difference as a primary metaphysical element and place identity only as a secondary principle – what he called a philosophical 'Copernican revolution' – Deleuze must accomplish another fundamental shift having to do with the concept of being: from a concept of equivocal being to a univocal one. In simple terms this step means the elimination of unique essentiality from being. The being of a stone, the being of a dog and the being of a poem are understood in the same sense though these entities are essentially different. Furthermore, and this is the important argument at stake, while being is progressively determined through unilateral differences, the sense of being remains unchanged. Univocal being is the only invariant but it is empty of any attribute apart from mere existence. With this shift, difference is established as the generative element of all that exists. It is important to note that difference is a virtual element and the plane of all interconnected differences is a virtual dimension. In relation to this field we can first address the concept of individuation – the progressive determination of individual forms, objects, relations etc.

Repetition – Passive Synthesis

The second building block of Deleuze's metaphysics is the concept of repetition. Again, conventionally, repetition is derived from identity – repetition is meant in the sense of repetition of the same. If repetition can be liberated from identity and re-conceptualized only in terms of difference, then, together, these can account for the production of all and everything. For there to be repetition, instances of repetition must differ from each other. The concept therefore cannot be rooted in the identity of repeating terms. Also, one needs to note that repetition does not happen in the repeating terms but among them and in relation to a background external to them. Such background must provide a means of accumulation of individual terms being composed together into a repeating series. Every instance of repetition involves the endurance of terms while they accumulate. The terms of repetition must hold among them a relation of interiority. Therefore, there is more to repetition than just a sequence of instances because in repetition they are synthesized into a continuum – the repetition itself. Every repetition is therefore a passive synthesis (a contraction in Bergsonian terms) forming what Deleuze called a sign that need not assume something or someone for whom the repetition is. Repetition can be multi-levelled as signs – contracted instances – can be further synthesized to higher level repetitions.

Repetition and Difference

There are three important points to note about repetition. The first is the conceptual inversion implied by the above understanding: the resemblance or identity of terms in repetition is an effect of repetition and not its condition. The second is that with this notion of repetition, series of differences can be synthesized into compound differences, which endow the virtual dimension of differences with a critical formative instrument. Third is that every actual repetition reflects a virtual repetition found in the multiplicity of the repeating differential element so that repetition is always two faceted: the repetition of sensible signs and the repetition of virtual differences that reflect each other.

Intensity

With the concepts of difference and repetition at hand the structure of the virtual aspect of reality can be further articulated. First, it is noted that series of differences constitute lines of synthesized progressive determination. These are reflected in actual lines of development or tendencies. Second, series of progressive determinations are possibly related to each other. Tendencies can affect and be affected by each other in a manner similar to how the variables of a dynamic system (and particularly the differentials of such variables) may co-depend. Tendencies and relations among tendencies remain entirely virtual and independent from anything sensible. In regard to affects, there is still an aspect of difference that requires further articulation – intensity. Intensity is the dramatization of difference. A unilateral determination is a formative aspect of difference. Yet differences have a dual complementary aspect of power or force that is associated with change. Every determination is hiding a power relation between that which wills to remain unchanged and that which wills to differentiate. This power vector inherent in determination is intensity – difference as intensity. A developing series of differences is also a developing intensity. Intensities are also apparent as one series of differences affects another series. Such a power relation is bi-directional but need not be symmetrical. Intensities, however, remain virtual. They do not cause change but rather reflect in the virtual dimension directions and mobilizing effects of actual change. Inasmuch as differences find their actual expression in changes of extensive and qualitative nature, intensities are expressed as the forces (or gradients) that mobilize these changes (see also 5.2.2).

Multiplicity

Before the whole architecture of the virtual is articulated, there is one remaining concept that needs attention – the concept of multiplicity. Difference in itself, being a unilateral determination, is inherently multiple. It appears as multiple yet being unilateral it is neither one nor many, yet partakes in both. Every difference repeats as it develops into series of differences (where the indifferent espouses them all) and becomes a multiplicity. Every difference may be the synthesis of an indefinitely fine structure of differences in itself, which is another multiplicity. Consequently the virtual can be said to have indefinitely complex and fully interconnected architecture — a multiplicity of multiplicities. Because of its interconnectedness, no part of it is excluded or separated from any other part. In this sense the virtual as a multiplicity is a pure interiority; it has no exteriority. However, certain constraints are implied by the architecture of the virtual even prior to actualization.

Ideas

The final and most complex element of the architecture of the virtual is the concept of Idea. Inasmuch as difference comes to replace identity, virtual Ideas come to replace the Platonic transcendent self-identical ideal forms. In that, the very idea of Idea is transformed. In a nutshell, Deleuze's Ideas are mobile configurations of series of differences and their intensive interrelations. In Ideas purely mobile differences bring forth ordered configurations that can be associated with actual systems.

Ideas (capitalized to differentiate the concept from its conventional use) are first and foremost problems. To have an Idea about something is to infer a problem to which that something is a solution. Ideas are like mathematical equations in that they specify relations among differences. Moreover, Ideas are not just any equation; relating differences they are rather like differential equations that describe dynamic systems. Further drawing on this metaphor, Ideas can be said to be undetermined configurations, as equations are, in relation to possible solutions; they can be considered determinable in as far as they can be shown to have a particular actual solution (and here there is a first indication of the significance of the actual aspect of reality); and finally Ideas may have infinite determination that can be thought of as a general solution to the equation that specifies infinite particular solutions. Understanding an Idea conceptually is exactly this: having access at once to all of its possible solutions.

If the variables of an equation are series of differences, the equation shows how these series of variables reciprocally determine each other, or in other words, it shows their intensive relations. Apart from the fundamental unilateral determination, reciprocal determination among series of differences is another phase in determining actual individuals. An Idea is fully specified by the number of the variables involved (its dimensionality) and the set of reciprocally determining relations among the variables. Every Idea specifies a multiplicity of possible solution objects.

Ideas remain purely virtual and since they are specified only as relations of differential elements, they have no identity. Ideas are intrinsically defined, that is, there are no external independent variables or elements. Finally, and most critically, Ideas must have an actual expression. There are no transcendent Ideas that are independent from the actual aspect of reality. Ideas are immanent in actual manifestations. Yet Ideas are also universal because they do not limit in any fashion the manner by which they might be expressed.

Thought as Genesis

The virtual structure conceived by Deleuze is a plane of interconnected Ideas. It is a grand multiplicity without any overarching order, unifying principle or identity. Thought as the genesis of actual manifestations is a process taking place not *within* the actual but *between* the virtual and actual. Thought (in its metaphysical sense) is the movement between the virtual structure of reality and its actual expression. Thought is also the movement from the problematic configurations which Ideas are to cases of corresponding actual solutions. This is thought as individuation and becoming – the ongoing unfoldment of open-ended intelligence.

Singularities and Significance

As virtual constructs, Ideas are never overt and always hide underneath their actual manifestations and their structure can only be inferred. To gain an insight regarding the relations between Ideas and their manifestations it is best to use the analogy of dynamic systems and their state-space representation. Even for relatively simple dynamic systems, it is often hard to formulate their dynamics in terms of clean differential equations and even harder to solve these equations analytically in order to learn the properties and behaviour of the actual system. Instead, it is often possible to characterize the system by computing or inferring its tendencies to behave in certain ways. The behaviour of dynamic systems is governed by moving along trajectories in their state-space representation and the shape of trajectories is governed by what are called attractors or singularities. These are like the topographic features of the state-space. By analogy, the complex differential relations that constitute Ideas give rise to trajectories in the course of determining actual forms and behaviours. The distinctive points of change in properties, form, or behaviour of actual expressions that appear during the development of an Idea into concrete form are in fact the unique characteristics of the Idea. These can be observed and are instrumental to the understanding of an Idea, even without knowing its exact analytical formulation. Distinctive points will appear repeatedly in all the manifestations of an Idea and will also keep certain relations among them. Other points in the development of any manifestation only follow a monotonous tendency until another distinctive point is reached. The contraction of developments between distinctive points into compound terms is the passive synthesis of differences already mentioned. The distribution of distinctive points within the space of development of an Idea (the space defined by the variables involved) is a topographic-like structure characterizing an Idea in terms that highlight change, disruption, turning and bifurcation points. In contrast to Platonic forms, the significance of the Deleuzian Idea is the manner in which it introduces difference and interrupts the continuity of expression. This significance replaces the inherent truth of the Platonic Idea.

The Plane of Consistency

All Ideas are interwoven together into a virtual plane or the plane of consistency. 'Plane' comes to signify that all Ideas are univocal. There is no hierarchy of being among Ideas though there may be structural hierarchies of expressing Ideas in actuality. Consistency means that there are no relations of contradiction or negation among Ideas. Series of progressive determinations (variables) can each participate in many Ideas and weave them together into a virtual fabric. Every Idea has an adjunct field of other Ideas that connect to it and share some of its dimensions. In the course of individuation, and depending on interactions among individuals, the expression of particular Ideas may change. It is always the case that in an actual individual certain Ideas are highlighted as distinct while other Ideas remain obscure. The particular highlighting and obscuration is due to actual interactions taking place among individuals. Relative to any Idea, the motion of individuation may be converging, that is, in the course of making its expression more distinct, or diverging (in flight), that is, in the course of making it more obscure. Importantly, the act of observation (the intervention of an observing subject) is such actual interaction and affects the manner in which Ideas are expressed. This is why observation inherently expresses a uniquely individual (and individuating) perspective. The whole dynamism of actual reality expresses at every moment the vast underlying plane of consistency. To further illustrate, actual reality is a kind of hologram in the sense that each individual expresses the whole of the virtual but with different degrees of clarity.

15.2 From Ideas to Individuals

Individuals and Individuation

The actual aspect of reality is complementary to the virtual. While the virtual is pure static structure, the actual is where dynamism and change are manifested. The elements of actual reality are individuals. These are unique objects, systems, processes, states of affairs, organisms, relations, thoughts and sensations etc. They are the actual players in the drama of existence. They are not beings but rather becomings. Critically, individuals are how Ideas are expressed – the product of progressive determination. In this sense individuals are the products of the event of cognition – the fundamental encounter that forces thought. In contrast to the Aristotelian system of thought, individuals are not the lowest derivatives of more general categories. Individuals are bottom-up creations. Every individual is a unique expression of the whole plane of Ideas but to different degrees of distinctiveness and obscurity. The uniqueness of expression depends on the interactions and assemblages an individual forms with other individuals. This dependency makes individuals inherently incomplete and unstable. Finally, individuals are the loci of individuation.

Deleuze's architecture of the virtual lays the ground for the shift from being to becoming, from identity to difference and from product to the productive. Difference is the primal element of thought, virtual Ideas are its structure. The next step is understanding individuation as the actuation of thought sans image – the formative process that brings forth representable forms and (relatively) stable identities.

Simondon's Theory of Individuation

Simondon's work on the genesis of being predates Deleuze and seem to have inspired Deleuze's treatment of individuation. Simondon's theory of individuation comes in response to criticizing two classical theories of being, the substantialist and hylomorphic. Common to the two theories is the presumption of a principle of individuation anterior to the process of individuation. In both cases there is a presupposition of either an uncreated individual or an *a priori* principle of individuation. Consequently an ontogenetic process of individuation must already be subjugated to individuals. In order for a process of individuation to precede individuals, three conditions must hold: first, that there is a preindividual reality, that is, a field of individuation; second, that individuation cannot stop; and third, that individuation cannot take place in vacuum, i.e., that individuation brings forth a partitioned existence of an individual and its milieu. To fulfil these conditions Simondon proposes a novel theory of being.

Being and Becoming

Simondon's metaphysical innovation is that individuation must take place *within* being – a becoming within being. For this to be the case, being must be posited as inherently mobile and incomplete, as containing a formative preindividual element that makes it always different from itself in itself. Due to the preindividual element, being is only partly individual and partly individuating – a being inseparable from its becoming. In Simondon's concept of being, the preindividual and individual hold a relation of interiority. Simondon draws a kind of a metaphorical cybernetic circuit: as long as being is identical to itself, it is in a stable phase. But once it spontaneously falls out of phase (because of the 'noise' of the preindividual) with itself, the resulting difference or 'error' drives an individuating change that brings it back into stability but in a different form, and then again...

Simondon's Process of Individuation

Individuation, according to Simondon, is driven by unresolved tensions existing in problematic situations. The problematic situation, that is, any situation where incompatibilities between elements invite resolution through change, is the model ground of individuating processes. An important point worth noting is that since there is no *a priori* principle of how individuation proceeds and since being has no constitutive principle of identity, individuation cannot be represented, modelled or predicted. It belongs to the realm of thought sans image and in this sense individuation itself individuates.

Metastability

The concept of metastability has a central role in Simondon's understanding of the relation between individuation and individuals. In concise terms, being, which was believed by the ancients to be stable, is actually a metastable entity and individuation is the manifestation of this metastability. The term is best understood by an analogy with the behaviour of dynamic systems. In a state space representing a map of the system's states, each state can be assigned a number designating the amount of energy the system has at that state. Energy here is not necessarily a physical magnitude but designates an abstract potential magnitude that mobilizes change. Intensity is in fact the differential of such potential magnitude. The states with lowest energy will tend to resist change and therefore are considered relatively stable, while states with high energy will tend to change and follow the shortest trajectory to one of the states with local minimum of energy. Therefore, such states are considered unstable. If the system is perturbed from a state of stability it will often (depending on the size of perturbation) reach a state of slightly higher energy and will tend to return to the initial state of lower energy, releasing to the environment the extra energy gained by the perturbation. A metastable system is a system with a number of local energetic minima. Given strong enough perturbations a metastable system may move among states of local stability; hence the designation metastable, which implies that no single state is truly stable.

Conventionally, the topography of the energy landscape is given and the system's dynamic will present a movement among an already determined set of stable states. Simondon's notion of metastability departs significantly from this scheme. Relations between variables in a preindividual condition are not yet determined and the topography of the whole landscape is undetermined too (or at least not fully determined). In the course of becoming, the individuating topography of the preindividual landscape gains local determinations, i.e., becomes progressively more or less individuated. Following such determinations the topography settles into more or less stable shapes as the state variables reciprocally determine their relations. The metastable being is not determined *a priori* but rather individuates along with its structure in a sequence of transitions. Metastability therefore does not mean merely multiple points of stability but rather a developing topographic configuration of such points.

Transduction

Simondon develops a conceptual mechanism of individuation which he calls transduction. Transduction shares many of the characteristics usually associated with self-organization but there are important differences. While self-organization is commonly described as the convergence of a dynamic process towards attractor states within an already configured state-space (i.e., an already individuated system), transduction does not assume such an *a priori* configuration. The significance of self-organizing processes is in their final product – the organization. In contrast, transduction is open-ended; organization is only an intermediate, relatively stable phase in the course of individuation. In most concise terms, transduction is a progressive co-determination of structure and action as the individuating system undergoes phase changes. Every structure determines the actions (and interactions) that may follow, and every action mediates between structural changes.

Deleuze's Process of Individuation

Deleuze's concept of individuation builds on the virtual structure he developed. The difficulty involved in this concept is the problem of how a dynamic world of individuals arises from a virtual plane which is static and causally sterile. What does Deleuze mean by "genesis without dynamism"? The virtual aspect of reality is atemporal, and individuation in Deleuze's theory, unlike Simondon's individuation, extends between the atemporal and the temporal. In individuation time itself individuates. Deleuze's point of departure is that every phenomenon is conditioned by virtual differences. Before addressing individuation, it is necessary to understand better what kind of explanatory paradigm Deleuze invokes regarding this conditioning.

Transcendental versus Causal Explanations

Conventionally, we explain things and events in terms of causative relations. If the existence of a set of conditions X guarantees that Y necessarily follows, then X is considered to cause Y and is the reason for Y to be the case. But causation is not a binding logical condition. Y is not logically deduced from the existence of X but rather inferred by X based on past correlated occurrences (repetitions). In this sense, causes are necessary but never ultimately sufficient reasons for something to be. Particularly, causal explanations fall short of explaining anything irregular, singular or creative. For this reason Deleuze does not lend much significance to causal explanations. If the elements of actual existence are individuals that are by definition unique and singular instances, causal explanations based on cases of repetition cannot be deployed to explain them. A different kind of explanation is needed.

Deleuze's claim that virtual elements are the sufficient reasons of individuals is derived from the relations they hold. Actual individuals are *expressions* of the virtual differences immanent in them. Virtual differences can never be sensed directly but can only be expressed. The actual aspect of reality is a dimension of expression that hides beneath it everything expressible. Here, one is reminded of the theme of exteriority and interiority developed by Bergson. Expression is the exteriority of things. It is the manner of their appearance in relation to other things, the way they affect (and are affected) externally. Virtual Ideas belong to the interiority of things, their 'in itself' dimension. In this sense, expression is nothing other than the exteriorization of interiority. Explaining the actual in terms of expression and expressed is a transcendental explanation because the sufficient reason for everything actual is inaccessible to direct experience. In this sense, observable causative relations are already expressions of virtual Ideas and virtual intensities.

The Synthesis of the Sensible

Expressions arise in a process of progressive determination in a manner analogous to how a specific trajectory of a dynamic system is determined by specific initial conditions. Determination that brings forth actual individuals is an interactive process taking place among individuals while they become. This is where the distribution of singularities in Ideas guides the manner by which actual intensities unfold in the interactions among individuals while they co-define their boundaries (see ahead).

Thought not subject to the image of thought – that is, thought as individuation – is driven by sensation. But this is not sensation as experienced by a human subject. The sensible or that which is given to sensation is the counterpart of expression. If the expression of X is how it can affect individuals other than itself, the sensibility of X is how it can be affected by the expression of other individuals. Expression therefore can be understood as the sensible for the other (not for itself). It is by sensation that individuals are moved to express certain Ideas that then, from time to time, gain identity by becoming temporally stable. It is also by sensation that actual identities are moved away from their state of stability to express other Ideas. Sense is how individuals affect and are affected by each other.

Intensities are the key to understanding sense. Virtual intensities expressed as actual intensive differences are the elements of sense – the differences expressed in one individual that affect the development of difference in another individual and thus participate in its progressive determination. Put differently, individuals can be understood as signal-sign systems. The word synthesis here again communicates the contraction of signals into signs. Whenever a developing series of differences meets a turning point, a threshold is crossed and a sign is produced – an element of expression manifested by the individual. This expressed sign, itself an intensive difference, can then affect other individuals. Individuals are none but the totality of the sensible signals produced. These totalities correspond to the distribution of singularities in the Ideas involved.

The Cancellation of Intensities in Individuating Phenomena

Actual expressions always seem to cancel the intensities that bring them forth. e.g., water flowing down the mountain cancels the difference in potential energy that brings it to move; eating eliminates the intensity apparent in the feeling of hunger that drives the organism to seek for food and feed; etc. There is a kind of apparent contradiction here. While actual intensive differences tend to cancel by bringing forth phenomena, their virtual counter-parts do not change. This reflects even a deeper puzzle: how does the dynamism of phenomena correspond to the static nature of the virtual? The answer to this apparent illusion lies in understanding that when intensive differences are cancelled, these are only exteriorized differences being cancelled. The cancellation being observed is only to do with which Ideas are distinctly expressed and which remain obscure. While the water is falling across a gradient, its dynamism expresses a certain Idea and specifically the actual energetic gradient corresponds to one of the variables of this Idea. But in the course of further individuation, the virtual difference being followed escapes the boundary of this Idea and is now participating in the expression of another Idea(s). Consequently, the phenomenon of falling water changes into something else. The actual energetic difference is equalized and there is a new landscape. The actual movement of the water is a signal delimited between two singular points of a developing difference. Before and after these points the Ideas being expressed are already different. Virtual intensities are never exhausted because they do not act or change anything. Only their expression is dynamic.

Metaphysical Self-organization Revisited

While identity-based metaphysical systems inherently account for being – the existence of things – the ontogenetic systems developed by Bergson, Simondon and Deleuze must explain existence, that is, why there is order rather than disorder, or why things have any persistence. Metaphysical self-organization is a hypothesis coming to explain being as a product of an underlying productive process. Organization per se cannot be its own sufficient reason. It must find its reason in the mobile metaphysical element. The concept of self-organization, which is a feature of the mobility that precedes more or less stable organizations, is there only to clarify that there is no underlying transcendent principle that imposes organization.

In Deleuze's metaphysical schema, indifference is determinable and differences as events of unilateral determination bring forth structure that is then expressed in actual more or less stable organizations (the formula of determinability, reciprocal determination and complete determination). But difference alone would not possibly be the sufficient reason for organization. It is only a necessary condition for reality to be different rather than indifferent. It is repetition and orders of repetition that are instrumental for organization and the emergence of individuated identities. Ideas are multiplicities and their individuation brings forth a multiplicity of unique individuals. The internal repetition in the Idea (its multiple nature) is expressed in the external repetition of individuals and forms populations of individuals. Only on the basis of this external repetition, can recurrent patterns, habits, similarities, invariants, generalities and all other signifiers of order be derived.

Another important aspect of self-organization arising from Deleuzian metaphysics is the symmetry breaking inherent in individuation. In the virtual, all ideas are univocal and equivalent. But individuation always highlights certain Ideas by expressing them clearly while obscuring all other Ideas. Distinct order always appears as symmetry breaking. Creative and destructive processes play complementary roles; the convergent articulation of certain Ideas always spells the dissolution of other Ideas.

Every Thing Thinks

With the metaphysical theory presented here, a concept of unsupported thought – thought sans image – arises that not only accounts for the origin of thought without the presumptions involved in representation but also frees thought from the particular thinkers humans are. In thinking as individuation, that is, the process of actually expressing virtual Ideas, there is a fundamental encounter, an event, that is free from any overarching method or principle. One can finally claim that in as far as every thing individuates, every thing thinks and is being thought. Here is where thought and being coincide and so are thinking and becoming.

The Event of Cognition

It is almost counter intuitive to think of humble objects or physical processes as endowed with cognitive capabilities and even less to consider them as thinking entities. Following the claim that thinking is a foundational formative process, the meaning of the concept cognition must be redefined. Cognition as opposed to recognition, which already implies thought within its image, is not an event of discovery but one of creation. The unknown does not become known via a process of discovery. The unknown is a creative field of difference and the known is born out of it in cognition. Thinking that takes place in bodies is thinking sans image; it is a becoming. The more something is stable, the more its thinking is arrested into recurrent patterns. The more something is fluid, the more its thinking is confused and does not express clearly any Idea. Significant events are those that realize a borderline of metastability. Thinking and cognition are two facets of individuation. While thinking highlights individuation as a vector from the virtual to the actual, cognition highlights individuation as the formation of boundaries among individuals through interactions. As boundaries form, signals consolidate into signs.

15.3 Influence on Human Thought

What would the application of thought sans image mean for human thought? First it provides an escape path from object-oriented, identity-based thinking. The ideas embodied in the metaphysical theory presented here suggest primarily openness, fluidity and an experimental style of thinking. At a more subtle level, there are profound influences on how a human might think. First, the manner of thinking and being cannot be entirely separated. One needs to accept a holistic integrated view of all the aspects of one's individual expression. Second, the underlying metaphysical interconnectivity invites an affirmation of the Other (not necessarily any specific other) and distances itself from negation and dialectical discourse. Importantly, the dichotomy of subject and object is relaxed and understood as a secondary effect and not as a fundamental reality. One needs to adopt a style of thinking *with* other individuals and not *about* them. Third, while object-oriented metaphysics is inherently resistive to change and marginalizes difference, difference-oriented metaphysics embraces change and accepts identity as secondary. Fourth, thinking is inherently creative; knowledge is created not discovered. The unknown is not divorced from thinking and is considered a creative field of individuation. It becomes an intimate aspect of thinking and becoming. Fifth, since all Ideas are univocal, the value of an expressed Idea is related to its significance rather than to its truth. Finally, these influences do not negate the image of thought presented in chapter 2; they rather expose the image of thought itself to further individuation.

Thinking Beyond Representation

Thinking with symbolic representations is foundational for language, social function, reasoning and interacting with the world. Yet it is limited by the same features that make it powerful in the first place. To be able to represent and manipulate reality in terms of clear and distinct objects and relations, it must neglect the ontogenetic processes that give rise to these representations. The limitations of thought as representation are difficult to realize, if only because the space of thought it allows is vast. Yet the space beyond thought as representation is much vaster.

Access to the realm beyond representation is gained by replacing identity with difference as the element of thought. This replacement prompts (among other things) the elimination of the sharp distinction between the known and unknown. Once the unknown is not neatly boxed into error margins and bounded uncertainty or is simply excluded and entirely disregarded from our reality, thinking necessarily becomes creative, open-ended, complex and all-encompassing.

The Image of thought and object-oriented thinking are already products of complex individuations. It is already thinking within thinking – a case where a thinking agent, objects of thinking and the relation between them are all distinctly individuated and form among them stable relations. But these apparent identities only arrest thinking into fixed patterns. There are always other individuations – lines of flight and escape routes from the conditions that define the thinker and the way thinking proceeds. These are not there awaiting discovery; they are becomings, unformed opportunities in the gaps between what is apparently given at every moment.

The Ontogenetic Nature of Thought

The most significant outcome of moving beyond the image of thought is realizing the necessity of an ontogenetic process that underlies being. Beyond the image of thought there can be little support to an 'out of nothing' ontological element. Thought must itself reach to the unthinkable and tap it directly without mediation. There can be no prior ground to thought other than the unthinkable – that which lies beyond thought. Thought as ontogenesis highlights the creative aspect of individuation and the baseless nature of such creation – the absence of a metaphysical "*a priori*". Ontogenesis proceeds in determinations where each such determination is a symmetry-breaking event as differences arise from indifference. It is symmetry breaking that brings forth actual expressions. Individuals always manifest certain Ideas clearly while all others remain obscure. This is the fundamental asymmetry of existence – not everything goes at once.

In more concrete terms, thought as ontogeny is expressed in three major categories of processes: *a*) processes of self-organization, *b*) evolutionary processes, and *c*) processes of cognitive development. In the light of the metaphysics of difference, these can be considered as special cases of thinking. Invariably such processes involve elements of contingency and random influences that introduce unpredictable turning points of convergence and divergence. It is due to such serendipitous events that no general formulations or models can be worked out for ontogenetic processes. These express the intimate role of the unknown in shaping the actual present and its significance.

The Universality of thought

Thinking as individuation is the fundamental process of bringing forth order in all its forms and modalities. Thinking spans as a continuum from the most elementary reciprocal determinations that constitute simple natural patterns (e.g., photons as the reciprocal determination of electric and magnetic differences) to the most complex individuations such as the ones taking place in brains, among brains, and in other highly complex systems.

Thinking as individuation is a universal process of actually expressing virtual Ideas. Importantly, this proposition falls short of automatically assigning significance to thought. Significance is never universal but rather sensitive to context and contingency. It arises in the symmetry breaking in thought. The vast majority of thoughts carry little significance.

Generally, the thinking – becoming of bodies is far from reaching the level of symbolic representation. The only individuated product such thinking brings forth is of *an image of a body in itself but only for bodies other than itself*. Such an image is the distinctive boundary of a body in relation to its milieu of all other bodies. It is how it affects anything other than itself and how anything other than itself affects it. In other words, reciprocal affect is how things make sense to each other and reflect each other's existence.

The universality of thought is not to be understood as to imply any kind of universal consciousness, sentience, or any other more or less mysterious psychic content. Thought as individuation comes to account primarily for the metaphysical roots of thought that precede representation, conceptualization and by extension any kind of a priori organizing principle.

Complexity Thinking

It is indeed widely accepted that the observable universe is highly complex, yet the idea guiding the thinking about the complex universe is that simple elements, relations and laws underlie all complex phenomena and can be discovered. In other words, this idea reflects a belief that the universe is, at least in principle, comprehensible by representing it as systems of components and relations.

In contrast, the metaphysical schema presented in this work reflects a universe which is fundamentally incomprehensible and where comprehension is the exception. This incomprehensibility, however, has nothing to do with the limitations of human intelligence or for that matter of any intelligence at all. It is rather a feature of the inexhaustible nature of the thinking process that brings forth a sensible universe. The universe, being fundamentally complex, can only be understood in complex terms, multiple concepts, perspectives, approaches and theories, all of which are experimental and never complete or final.

The prospect of developing complexity thinking as an independent paradigm must accept and experiment with thought beyond image and thereby beyond what is given to conventional reductionist reasoning and empirical observation, which are the corner-stones of dogmatic scientific investigation. Complexity thinking, however, does not come to criticize the scientific method or replace it. It only aims to address the kinds of phenomenon where the scientific methods fall short.

Thinking the complex goes beyond the concept of system as it is conventionally used in the term 'complex system'. This concept is already a product of individuation given in terms of components and relations. Relating to general systems as cognitive systems (see ahead) incorporates into systems thinking formative individuating processes where system boundaries are formed.

Open-Ended Intelligence

If it is the case that thought as individuation is universal, there is also a case to associate with it a unique kind of intelligence which is universal and exceeds the notion that subjugates intelligence to some kind of purposeful goal-oriented activity.

This kind of intelligence can be associated with understanding virtual Ideas to be problematic instances and thinking of individuation as a problem solving activity at the metaphysical level. The products of individuation – intricate patterns of order, elegant and simple relations between multiple elements etc. are most intuitively accepted as manifestations of intelligence. There is therefore a case for relating intelligence to individuation, but since the kind of intelligence that would fit such a case is not defined by a goal, a final reason, or a capacity to produce measurable results in a specific operational milieu (e.g., body coordination, human communication, survival skills in a certain environment, autonomous driving, optimal planning, winning Go games, etc.), it would most appropriately be termed open-ended intelligence.

Inasmuch as everything thinks and is a thought, everything is inherently intelligent. But it is a kind of intelligence which is not a property or a capacity of anyone or anything. Open-ended intelligence is inherent in individuals in as far as they individuate, that is, in the course of expressing intelligent forms. The intelligence underlying evolutionary processes is an exemplar of open-ended intelligence. There is no need to associate this intelligence with either its actual manifestations (the organism) or an imaginary agency (a ″designer″ or ″creator″).

It is argued that open-ended intelligence is more fundamental than all other kinds and notions of intelligence because these are already individuated products of it to a higher or lesser degree. Open-ended intelligence embodies a borderline similar to the one existing between thought and the unthinkable or knowledge and the unknown. Open-ended intelligence is the becoming intelligent – the differential between the unintelligible and the intelligent. The designation 'open-ended' signifies inexhaustible possibility but it also signifies the incomplete and ungraspable in intelligence as it embraces also that which it is not and yet to become.

15.4 Actual Individuation

Building on the metaphysical framework presented and the conceptual development of thought from difference to actual individuals, we further address the problem of understanding individuation in terms of general systems thinking. While classical systems thinking can be considered an epitome of representation-based philosophy, we aim to introduce a framework that derives from an ontogenetic approach and expands systems thinking beyond representation into the realm of complexity thinking. The nexus of such framework is actual processes of individuation as they are reflected in cognition, where cognition is understood as the formation of boundaries and distinctions. The development of the framework involves three complementary aspects: *a*) developing the concept of systemic cognition as the individuation of general systems, *b*) understanding the distributed nature of systemic cognition, and *c*) understanding interaction as the fundamental mechanism underlying the individuation of systems.

Cognitive Science

Modern cognitive science is an amalgam of quite a few disciplines of thought and research methods including psychology, philosophy, phenomenology, linguistics, anthropology, neuroscience, computer science, artificial intelligence and more all aiming to understand the mind, its evolution and its workings. The systemic approach to cognition aims to characterize and understand general cognitive systems and distil definitions, mechanisms and principles that apply equally well to both naturally evolved living systems, e.g., microorganisms, individual complex organisms such as humans, hives and swarms etc., on the one hand, and artificial systems such as robots, computers, computer networks, corporates, social organizations, etc., on the other. Here we aim to extend the concept and make the case that there is a deeper and more fundamental sense of cognition which is to do with the individuation of systems and the knowledge creation that precedes fully individuated systemic organizations and is instrumental to their becoming. This sense of cognition underlies all forms of actual organization.

Cognitivism

In the course of the 20th century, cognitive science underwent a few important paradigm shifts. In historical perspective, cognitivism which emerged just before mid-century together with cybernetics is the first highly influential paradigm. To an extent, and in spite of a few competing paradigms that flourished since, cognitivism is still a leading textbook dogma to this day. The highlights of cognitivism is that cognition is a rule-based symbolic computation carried out by a system analogous to a digital computer. Symbols are representations of states of affairs in the world including the sensorimotor interactions of the organism. The rules involved are either genetically hardwired or the result of a process of learning and adaptation. The syntax of symbols and rules mirrors their semantics, i.e., what they represent, and therefore cognition need only involve syntactic manipulations and has nothing to do with meaning per se. Finally, cognition is effective, given that symbols indeed correspond to real states of affairs and the symbolic computation amounts to the organism (or cognitive system in general) solving problems in the context of its actual environment. Cognitivism clearly reflects what we call the image of thought presented in chapter 2. Such correspondence entails that cognition amounts to forming a more or less faithful model of an *a priori* given world and devising proper responses to various stimuli via rule-based manipulation of the model. Additionally, for cognitivism to work, one needs to assume a world given in terms of more or less discrete and predictable identities and their relations. In fact, cognitivism is a specific derivation of the image of thought that equates thinking to computation and perception/action to input/output operations.

Connectionism

Alongside cognitivism an alternative paradigm of cognition emerged, called connectionism. Connectionism replaces the primary metaphor of the digital computer with a complex network of fairly simple elements inspired by the structure of the brain. In the connectionist paradigm there are no explicit rules, no symbols and most importantly no central control. Instead, simple local dynamics bring forth global coherent states and effects involving the whole network or large parts of it. The local elements are said to self-organize and together manifest cognitive functions that none of the individual elements can possibly realize. These functions are termed emergent properties – global effects arising out of local interactions. Cognition in the connectionist model is distributed, resilient and plastic. There is no single element that is essential. Every function is multiply realized and every element partakes in multiple functions. Learning and adaptation is simply achieved by changes in the connectivity of the network.

Towards Enactivism

The most important departure of the connectionist model of cognition from the symbolic one is that there is no clear sense of representation. The connectionist paradigm admits no internal models or representations of an outside given world. Instead, the network acquires a holistic model of the world and interacts through it. Clearly, the connectionist paradigm makes far fewer assumptions about the world and about how cognition is realized. Yet from a certain perspective both paradigms suffer from a shared fundamental weakness: they neglect the relation between the cognitive process and the world. The mind and the world are treated as separate, with the outside world mirrored by a representational model inside the head. During the 1990s a new paradigm came to the fore, called embodied dynamicism. Similar to the connectionist paradigm it focuses on self-organizing dynamic systems rather than on discrete symbolic manipulations. Its core innovation is in approaching the mind as an embodied dynamic system in the world. Embodied dynamism sees cognition as a process taking place in the world and with the world, rather than a process about the world yet isolated from it.

What is Enactive Cognition?

Fundamentally, enactive cognition is the hypothesis that cognition is the product of activity and more specifically of the activity of a cognitive agent in the world. The enactive theory of cognition was conceived by Varela and addresses the fundamental problem of the subject of cognition meeting a world of its own doing. Influenced by his work with Maturana, Varela saw cognition first and foremost as a biological activity. Three concepts are central to his novel approach to cognition: autonomy, the structural coupling of an autonomous system with its environment and the way autonomous systems transform.

Most concisely, cognition is an embodied action that enacts – brings forth – a world, where enaction means a history of structural coupling between the cognitive agent and its milieu. Such coupling can be operationally understood as perception that consists of perceptually guided action, or in other words, perception as an activity that itself is guided by outcomes of previous perceptions. In the course of such activity, cognitive structures dynamically emerge from the recurrent sensorimotor patterns that enable action to be perpetually guided. In enactive cognition, embodied interaction rather than a pregiven world determines how the cognitive agent acts and how it affects and is affected by its milieu. Enactive cognition embraces the cybernetic idea that allows circularity of cause and effect. It eliminates the dichotomy apparent in cognitivism and connectionism between mind and world. The cognitive agent and its milieu are bound together in reciprocal determination and selection where every action is both a response and a trigger to further stimulus. The product of cognition is an environment which is neither an *a priori* given agent-independent world nor a construction or projection of the cognitive agent's mind. The environment is first and foremost an ongoing joint individuation.

Embodiment

Embodiment is not a concept unique to enactive cognition. The most common understanding of embodiment in cognitivism is the dichotomy between mind as 'software' and the brain as 'hardware', where the latter is the embodiment of the first. A similar separation exists whenever the mind is understood as a function that operates and is realized within a certain physical substrate or context e.g., the control system metaphor whereas the mind is a controller that regulates the physical activities of the body. In contrast, in the context of enactive cognition, embodiment is a compound of three sets: a set of sensors (and sensory processes), a set of actuators (and motor processes) and a set of structures that link and cohere between perceptual events in the first set to action events in the second. It is the specifics of these three sets that are determined by the history of structural coupling between the agent and its milieu. The embodiment of the agent is integral to the milieu which is sensed and can be acted upon. The agent's embodiment and the milieu must be given in the same descriptive domain so their interactions can be described within that same domain.

In most conventional cases and disciplines of study, bodies and objects are individuated, i.e., made distinct from their milieu by applying some conventional criteria. In contrast, according to the theory of enactive cognition, bodies are always self-individuating. They actively (or passively) generate and maintain a distinction between themselves and their milieu. The theory sees this self-individuating activity as one of its central features. Cognition brings forth autonomous bodies.

Autonomy and Closure

The idea of autonomy has its roots in the theory of autopoiesis. Autonomy is a more general concept, which captures two related properties. The first is self-individuation, that is, the capacity of a system to distinguish itself from its milieu. The second is the capacity of the system to specify its own norms and laws, which are applied in its interactions with the rest of the world. What constitutes an autonomous cognitive agent is the above mentioned collection of sensors, actuators and additional components organized in a manner that is self-individuating and regulates its activities/ interactions according to norms that are intrinsic aspects of its organization.

How are these related properties realized? Central to the realization of autonomy is the concept of operational closure. A set of processes P, all described in the same operational terms, is operationally closed if for every process in the set the following holds: *a*) the process is a necessary condition for the operation of one or more other processes in P, and *b*) the process is conditioned by the operation of one or more other processes in P. If these relations hold, the set P forms a network of processes conditioned by each other in such manner that the overall operation of the network is necessarily maintained by the operation of each and every component in the network. Operational closure, however, does not mean that the overall operation of the network P is independent of other processes that are not part of it. This operational dependency distinguishes P from the background of any larger set of processes. Operational closure can be said to realize a self-individuating entity. It produces and maintains its own identity in terms of being differentiated from its milieu.

Di Paolo argues for a stronger kind of autonomy, which he calls a precarious autonomous system. Precariousness means that the processes constituting the closure must have the property that once partly or fully isolated from the closure, they will tend to degenerate and cease. In other words, the operationally closed organization is critical to the maintenance of its component constituents as well as to the maintenance of their joint organization. In a precarious autonomous system, the closure as a whole operates against the otherwise natural tendency of the component processes to degenerate. In this, the closure fulfils a much stronger role than just maintaining itself. It actively enables itself.

It is only on the basis of a precariously generated identity that an autonomous system can assign a non-trivial significance to its various interactions with its milieu (interactions actually performed by its component processes) as these become critical to its very continuation. The precariousness of identity in autonomous systems, therefore, is instrumental to the establishment of norms and the regulation of activities according to such norms. Operational closure provides the explanatory ground for enactive cognition. What needs further explanation is how autonomous agents engage with their milieu and in what manner they bring forth a world.

Structural Coupling

Two structures are said to be coupled when there exists a history of reciprocal perturbations between the structures. Importantly, the perturbations themselves are not instructive as to the nature of change that they have triggered. Such changes are determined by the structure being perturbed. In some cases these structural changes elicit actions that introduce further perturbations. When exchanges of reciprocal perturbations become recurrent, there is structural coupling between the structures and they share a history of reciprocal perturbations. Enactive cognition is realized as structural coupling between the cognitive agent and its milieu.

An autonomous system undergoes many structural changes while maintaining its operational closure, that is, its identity. The set of all structures that are still mapped to the same autonomous organization are termed the system's viability set. The perceptually guided actions that constitute enactive cognition are directed towards increasing the probability of future perturbations that trigger structural transformations only within the viability set. Only on account of maintaining autonomy do perturbations gain significance in relation to the agent's state of affairs. Perception, inasmuch as it can be guided by action, can be dynamically positioned towards the milieu in such a fashion as to better inform future actions based not only on the immediate perturbations but also in regard to tendencies of future perturbations to be beneficial or detrimental to the agent's autonomy. This is how the actions of the agent become not only perpetually guided by its perception but also anticipatory; hence enacted cognition. Cognitive structures emerge dynamically from the recurrent sensorimotor patterns. Together they constitute for the agent the environment it brings forth, which is significant to the maintenance of its autonomy and is practically inseparable from it. Importantly, the actions of the agent also shape the agent's milieu and indirectly transform it to fit the agent's activities. Consequently, the environment and the agent display a remarkable fitness to each other.

Natural Drift

In the same manner that a cognitive agent is self-individuating and in that brings forth a world, so by analogy the evolution of a biological species can be said to be a case of self-individuation where a species brings forth a world – the ecosystem in which it survives. Evolution can therefore be seen as cognitive activity but at a different time scale and with a different kind of agency. The parallelism of cognition and evolution lends ground to the hypothesis already developed earlier in the thesis that both are instances of individuation.

Much of what constitutes an organism in the case of evolution or the world brought forth by cognition is under-determined by the constraints imposed by the respective milieu. There is therefore a vast space of variability for individuation to take place. The bringing forth of a world is therefore not conditioned by a notion of a pre-existing milieu. Evolution (and likewise cognition) as natural drift is a process taking place within an history of structural coupling and where structures drift within their viability set while being pruned from time to time so as only to select out trajectories that are not viable. The argument of natural drift in cognition and evolution comes to make the case that individuation that brings forth cognitive structures or individual organisms is not bound and is not solely guided, in most cases, by constraints derived from the optimization of fitness to predetermined circumstances.

Based on the mechanism of structural coupling, cognitive agents and their milieu stand in relations of progressive reciprocal determination that realize their ongoing individuation. Identities, objects and recurrent patterns of behaviour (habits) all arise from a play of perturbations – differences that trigger other differences – i.e., intensities. In enactive cognition as a systemic theory we find therefore a candidate of an actual mechanism that accounts for the emergence of identities out of recurrent and reciprocally determining series of differences. It is this alignment of the systemic and metaphysical that lends significance to the idea of natural drift. Without it, we could not have escaped from positing a pregiven world, which is equivalent to positing an identity that precedes difference and guides its development.

Sense-making

Autonomous systems regulate their structural coupling with their milieu so as to direct the unfoldment of such coupling towards the maintenance of their identity. In that, they "cast a web of significance on their world". In other words, autonomous systems make sense of their milieu and bring forth their environment as sensible with its intrinsic meanings and values. The invariants, e.g., objects, relations, behaviours, know-how etc., which appear as the products of cognition in the agent's environment are an outcome of a joint dynamism of agent and milieu. These already appear with an intrinsic significance according to their relevance for autonomy.

There is, however, a deeper understanding of sense-making. It is not sufficient that an autonomous system will be able to respond to perturbations while remaining within its viability set. The system will gain much advantage in maintaining its autonomy if it can monitor the tendencies of the current perturbations it is exposed to and anticipate whether such tendencies lead its current trajectory of structural changes towards or away from the boundaries of its viability set. If such anticipation is possible, the system can act in advance so as to regulate its own structural coupling, modifying prospective harmful trajectories into beneficial ones. This kind of adaptive regulation can be considered as the hallmark of sense-making activity and of cognitive agency. Such a notion of sense-making can be well understood and explained in terms of cybernetic regulation based on self-created norms. The norms, if made explicit, also provide a set of defining (invariant) properties for an identity.

This concept of sense-making is problematic for a number of reasons: *a*) Sense-making only 'makes sense' on the basis of an existing autonomous system. It must assume a pre-existing identity from which norms are derived. Consequently, the world enacted and brought forth in enactive cognition is a projection of an *a priori* identity. But this begs the question of how cognitive systems come to establish autonomy in the first place. How does cognition develop from non-cognition? *b*) When self-individuation and adaptivity are combined, it is no longer clear whether the maintenance of identity must mean the continuation of the same identity or the continuation of any identity. Adaptivity understood as keeping structural transformation within a viability set can be achieved not only by regulating structural coupling with the agent's milieu but also by reshaping the viability set itself. This points towards an extended understanding of cognition.

Sense-making sans Maker

Can there be sense-making prior to autonomy and identity, i.e., sense-making without sense-maker? Can cognition be enacted without an actor? The weakness of enactive cognition is that it does not account for the becoming of the cognitive agent. The enactive agent is in fact self-individuated but not self-individuating. A true self-individuating system is a system capable not only of maintaining identity but also of undergoing transformations of identity without losing its overall coherence and integrity.

By understanding autonomy as self-individuating and not only self-individuated, inevitably sense-making becomes a formative process that can also precede autonomy. It is not merely the activity of maintaining an already existing identity but rather a transformative process of an identity continuously in the making. Once enactive cognition is acknowledged as formative it can be thought of as consisting of two interwoven aspects: the bringing forth of a world and the bringing forth (individuation) of an identity in the world. The latter is associated with cognitive development. The sense-maker becomes variable, i.e., it can differ from itself in the course of sense-making. The processes that cause closures to form or disintegrate are not different in nature from those structural transformations that maintain closure.

Boundary Formation

The concept boundary is closely related to the concept of the individual. In as far as an individual entity is distinguished from its milieu in any arbitrary fashion, there exists a property space where both the individual entity and its milieu can be represented as separated by a geometrical boundary. Extending the analogy, the idea of boundary formation intuitively corresponds to individuation.

Structural coupling implies a boundary between the agent and its milieu across which perturbations are exchanged. If there is a boundary, some degree of individuation must be assumed. Sense-making preceding autonomy can be understood as the spontaneous emergence of a system-milieu boundary in a network of interacting processes. The partition of a network of interacting processes into subnets can be initially serendipitous (as in a natural drift) and possessing no intrinsic tendency to persist. The specific causes involved in the appearance of the boundary are not of importance as long as the emerging boundary is intrinsic to the network activities and not externally imposed. Once there is a boundary, interactions among the members of the network gain a distinctive significance: they can be categorized as interactions taking place across the boundary, or interactions not taking place across the boundary. The formation of a boundary casts therefore a primitive significance over the network and hence it can be considered as a primitive event of sense-making. What such spontaneous sense-making allows is the consideration of structural coupling prior to autonomy and independently of an observer external to the network.

Fluid Identities

The idea of fluid identities is an extension of enactive cognition based on replacing the notion of individuals with individuation. A precarious autonomous structure requires that an operational closure must be maintained continuously in the course of structural coupling. This requirement can be restated: a precarious autonomous structure requires that its operational coherency be maintained in the course of structural coupling. This means that critically the very property of closure must be maintained but it does not necessarily mean that *it is exactly the same closure that is maintained*. Operational coherency is not conditioned by the identity of the component processes of the closure but rather by an overall alignment of their dependencies. As a result, identity can radically change its defining properties while maintaining an inner operational coherency along the process.

Fluid identity is the only proper description of a continuously individuating autonomous agent. That we tend to describe the world in terms of stable identities is only a habit. In the extended version of enactive cognition there is a continuum of sense-making activity that can be divided into phases, from the relatively vague preindividual boundary formation phase, through the fluid identity phase, to the highly individuated (i.e., high level of determination) self-maintaining adaptive identities. This continuum is also reflected in the history of structural coupling. In the phase of boundary formation, the incidence of recurrent patterns is low while towards the phase of highly individuated agents such incidence tends to increase.

It is important to note that boundaries can form and passively persist indefinitely in the absence of disrupting perturbations (natural drift). Stable individuals thus formed need not necessarily reach autonomy in the strict sense described above. They nevertheless still resist change due to the configuration of their interactions and in this sense can be said to passively self-maintain. There is a continuum between passively persisting individuals and actively adaptive ones.

Cognition and Systems

The very concept of system already indicates an organization of more or less stable components, states, relations and behaviours. Indeed in many cases assuming a stable organization is an obvious and extremely useful simplification. For complex systems, questions such as what the system's boundaries are, how it may further individuate, etc. become significant if not critical. Systemic cognition is the system-theoretic counterpart of the metaphysical event of cognition mentioned earlier. It highlights the significance of cognition and sense-making to the understanding of the formative individuating aspect of actual systems coming into play as processes of boundary formation and transformation of identity.

Furthermore, in the application of the proposed extended version of enactive cognition to systems, terms such as "perceptually guided action" and "sensorimotor patterns" can be extended to fit the conceptual frame of individuation. An abstract sense of perception can be associated with anything capable of being affected by something else. Similarly, an abstract sense of action can be associated with anything capable of affecting something else. Perception and action in such a broad sense correspond to sensibility and expression and are actualized as instances of signal-sign exchanges. Finally, there are possible recurrent correlations between these two abstract notions that can be inferred. These correlations correspond to the reciprocal determinations intrinsic to the underlying Ideas being expressed by the system. These correspondences are sufficient to present individuating processes as perceptually guided action, that is, cognition.

This approach to systems is what broadly frames a systemic concept of cognition. Within such a framework, all systems are cognitive and systemic interactions constitute a continuum of cognitive activities at multiple levels of granularity. The advantage in relating to systems as cognitive is profound as it seamlessly introduces the formative aspect into systems thinking, incorporating the evolutionary and transformative processes of systems.

The Distributed Nature of Cognition

Systemic cognitive processes synonymous with individuation processes are distributed with no intrinsic centre. The formation of boundaries, distinctions and individuals takes place within populations of interacting individuals of a lower stratum. There is special significance to showing how distributed cognition in actual systems reflects their virtual multiplicity and how such multiplicity is externalized in populations of interacting individual entities.

Population Thinking and Individuation

Evolution theory replaced the concept of species as natural archetype – a preexisting abstract identity that precedes all the actual instances of organisms that exemplify it – with the concept of species as a population of individuals. The concept of natural types sees in species an ontological category and the apparent variation in nature as secondary and rooted in a limited number of fixed forms. Evolution theory, in contrast, places the highest significance on the variation presented by individual members of a species and not on the characteristics common to them. The metaphysical understanding implied by modern evolution theory is that unique individuals are the real ontological elements while species are only a reification characterized by statistical measures (on that see ahead).

Population thinking is a perspective that attempts to describe and explain certain phenomena in terms of collections of unique individuals and the properties and behaviours they collectively bring forth. Focusing on difference, two primary characteristics of populations are heterogeneity and diversity. By heterogeneity we mean a range of qualitative differences characterizing the individuals belonging to the population. By diversity we mean a range of quantitative differences, i.e., degrees of expression per specific quality characterizing the individuals belonging to the population.

Population thinking also considers interactions among the individuals belonging to the population and, on a higher scale, the interaction between populations actualized as interactions between individual members of the populations. Through interactions populations become fields of ongoing individuation: *a*) individual members may further individuate, *b*) new individuals can emerge as the members of the population become coupled via recurrent interactions, and finally *c*) the population as a whole may individuate. Furthermore, the idea of treating whole populations as individuals is perhaps the most powerful and interesting feature of population thinking. The exemplary case is of biological species as individuals themselves constituted by individual organisms. Populations as individuals carry all the important marks of an autonomous self-individuating precarious entity, i.e., a cognitive system. In the broader picture, it is easy and almost natural to understand inter-species dynamics in terms of interacting individuals. From a metaphysical perspective, populations are the actual (externalized) counterparts of virtual multiplicities. Boundaries and interactions across boundaries are the more or less distinct expressions of virtual Ideas. The theory of enactive cognition and its extension to systemic cognition fits naturally within the framework of population thinking. Boundary formation, the emergence of closures, and the bringing forth of a world through structural coupling can all be given in terms of a population of interacting individuals.

Assemblage Theory

Assemblage theory is an aspect of population thinking that focuses on the characterization of interactions and processes taking place between individuals. The premise of the theory is that individuals are metastable constructions that consist of other individuals. We term such constructions assemblages. These are individuals in the making that can be found at diverse states of consolidation and coherence. Assemblages are far from being monolithic, coherent and stable. They are rather precarious structures whose very existence is often contingent. They often hide inner tensions, just barely containing an ongoing state of crisis as to their integrity and identity.

An assemblage is a network of interacting heterogeneous individuals that brings forth an individuating yet not necessarily fully individuated entity. The elements of an assemblage are characterized by *a*) identifying properties that define them as the individuals that they are and are subject to their own individuation, and *b*) capacities to interact – affect and be affected by other elements. The second set of characteristics, depending on actual interactions taking place with other elements, is by definition open-ended and non-deterministic. The relatively independent individuality of elements allows elements to be detached from one assemblage and reattached to another without losing their own integrity. As elements connect and disconnect serendipitously, an assemblage may transform radically via novel interactions and via connecting to or disconnecting from new elements. The reason why the properties of the assemblage as a whole cannot be reduced to those of its parts is that they are results not only of an aggregation of the components' own properties but (perhaps primarily) of the actual exercise of their capacities to interact.

Unlike systems, there is no overarching pattern or organization principle that applies to an assemblage making it a whole. While the relations between the components of a system are a result of a logical necessity derived from an organization principle, the relations that hold within an assemblage are contingently obligatory, that is, they derive only from the history of coupling between the interacting elements.

The concepts describing systemic cognition can all be described in terms of assemblage theory, highlighting their distributed nature. Thinking in terms of assemblages is useful for clarifying further the ideas of boundary formation and fluid identities. The dynamic aspect of assemblages can be described in terms of territorialization and deterritorialization. These two concepts qualify (respectively) to what extent a certain process (a set of interactions) contributes to the overall distinctiveness, coherency and unity of an assemblage, i.e., reinforcing the assemblage's identity, and to what extent it works against those characteristics and towards dissolution of boundaries, increase of inner tensions and disparity, i.e., disintegrating the assemblage's identity.

The individual components of assemblages play two major kinds of role in their interactions, termed material and expressive. The material role is to do with the structural aspect of the assemblage while the expressive role is to do with how it affects (and is affected by) other entities. The chemical composition of nucleotides and their capacity to attach chemically to each other in arbitrary order and form DNA strands is their material role. The manner in which they code for protein structures is their expressive role.

Stratification of Systemic Cognition

Depending on specific contexts and systems, it is worth identifying multiple strata of nested individuals where each stratum is seen as a distinct population, e.g., cells, multicellular organisms, species, ecosystems (see further 8.3) etc. Stratification into hierarchical structures, however, does not bear on the proposition that metaphysically only individuals exist. There is no hierarchy of being among individuals.

Considering a large and heterogeneous population P_0 of interacting individuals, stratification happens if recurrent interactions in P_0 bring forth a new population P_1 of relatively stable compound individuals which is itself large and heterogeneous enough to provide circumstances for the further emergence of populations $P_2, P_3, \ldots, P_n$ in the same manner. Processes of stratification are probabilistic in nature and have both bottom-up and top-down aspects. The individual elements of populations have rates of production and disintegration that depend on the frequency of interactions with territorializing and deterritorializing effects respectively. For multiple strata to emerge, individual elements need to be stable enough to allow high enough probability of interaction with other elements. As compound individuals form in large enough numbers, they have an effect of constraining the interactions of their components. Such constraints can be understood as additional determinations in the course of the components' process of individuation, further consolidating their identity (i.e., territorialization). The probability distribution of formative processes affects the population in such a way that certain constructs become much more probable while others become much less. In a broader view this would mean that certain trajectories of future development of higher strata are suppressed or eliminated while other trajectories are reinforced. This is how a stratum can exert selective influences, on both lower and higher strata.

The idea of systemic cognition suggests that individuals have an intrinsic granularity, that is, an intrinsic substratum of elements and interactions that constitute them and in which the history of their structural coupling is expressed. Stratification is a process of systemic cognition which derives from the individuals of the substratum and their capacities for interaction. No cognitive structure is brought forth in isolation. It is always a whole population of individuated structures that is brought forth.

Coding

Following the ideas developed above, a coding system is a language-like formal system with a finite set of symbols (signs) and a finite set of syntactic rules that specify how compound individuals are produced, that is, how expression is generated from structure (the material aspect) in assemblages of elements. Coding systems are mechanisms of combinatorial productivity; they produce diverse expressions by forming combinations of elements according to their given rules. Such systems are themselves a product of earlier individuation and normally represent a stratum of individual elements and their interactions. As such they constitute a ground that facilitates further individuation. In the course of stratification, a few such coding systems may emerge one on the top of the other, each with its own elements and syntax.

The concept of representation and thought as representation can be understood in terms of coding systems. A thought (in the broad sense we mean in this work) is supported in as far as it can be described within at least one coding system. The whole idea of support is rooted in the existence of a finite coding system. Certain thoughts can be given finite descriptions while other thoughts can only be given infinite descriptions but still using finite sets of elements and combinatorial rules. Finally there are those thoughts that are entirely unsupported because no coding mechanisms exist for them as yet or can exist at all. In the context of understanding thought as individuation, one of the most interesting topics for further investigation is the individuation of novel coding mechanisms.

Assemblage theory and the stratified articulation of individual entities in populations provide a framework for describing cognitive and evolutionary formative processes of general systems. This descriptive framework is not confined to any specific discipline or category of phenomena and can easily be deployed across multiple disciplines and categories.

Individuation and Information Integration

The qualitative concepts regarding the distributive nature of individuation can receive a quantitative perspective using information theory and specifically the concept of information integration. The idea behind information integration is that given a population of interacting processes, and a subset of processes within the population, it is possible to quantify to what degree the processes within the subset are interactive and compare it to the degree of interactivity between the subset as a whole and the rest of the population. Such measures provide an approximate analogue to the degree of individuation and distinctiveness of subsets of processes in the population and possibly can be used to reflect stratification and the granularity of emergent strata.

It has already been argued that individuation cannot be formalized or mathematically modelled. The concepts discussed here are therefore simplified approximations based on the assumption that once we consider a population of already individuated elements, and these are relatively stable, as well as their distribution in the population, we can express their properties and interactive capacities in terms of information theory. In such cases, boundary formation and the individuation of compound entities can be approximated as clustering processes. In general, individuals are not clusters because what holds them together are interactions and not the common properties of their elements. But as the behaviours of elements become correlated and they form more or less stable interactive networks, there is an aspect of clustering to individuation.

Consider a set X with X_i elements where each element is an individual process with a repertoire of states S and a probability distribution $P_{X_i}(S)$. The function $\Phi(X)$ – the information integration of X – can be interpreted as the minimal amount of information exchanges involved in interactions within X. Using Φ, structures called complexes can be defined. A complex is any subset $A \subset X$ for which there is no other subset $A^{'} \subseteq X$, such that: *a*) $A \subset A^{'}$, and *b*) $\Phi(A^{'}) > \Phi(A)$. The rationale behind this definition is that if $A^{'}$ is with the greater Φ, it means that A is only part of a larger and more integrated network of interactions.

The idea of information integration is applied in the context of individuation and systemic cognition to indicate an approximate measure of individuation. The dynamism of individuation can be reflected in $\Phi(X)$ and in the structure of complexes once we allow that interactions within assemblages are not fixed. Since elements can join and leave an assemblage and interactions appear and disappear, X and the interactions among its elements dynamically change. Consequently, also $\Phi(X)$ evolves and the structure of complexes is to be considered as dynamic.

Boundaries and Distinctiveness

Considering the relations between X and a larger population P, it would be interesting to express the distinctiveness of X in its milieu using informational terms. If X is a complex, there is no subset $X^{'} \subseteq P$ so that $X \subset X^{'}$ and $\Phi(X^{'}) > \Phi(X)$, meaning specifically that $\Phi(X) > \Phi(P)$. We can then define the milieu of X as $Mil_X := P \setminus X$ and develop expressions for the interactions of X and Mil_X. In consideration of the history of interactions, the concept of transfer entropy can be deployed to develop explicit expressions of the information transfer $T_{Mil_X \to X}$ from the milieu to X through its perturbations of X. This can be qualitatively interpreted as the information gained by an agent X's perception. Similarly, the expression $T_{X \to Mil_X}$ for the information transferred from X to its milieu can be qualitatively interpreted as the information transferred to the milieu by the actions of X.

The combination of these expressions shows that some of the information transferred from X to its milieu by its actions is recurrently fed back to X via its milieu as perceptions. This informational feedback corresponds to enactive cognition as the history of structural coupling between X and its milieu. These formulas are not necessarily useful as they are but they nevertheless express the coupling between an agent and its milieu even prior to the emergence of closure. Before any individuation takes place the information being transferred would simply be noise. But in the course of boundary formation, $T_{Mil_X \to X}$ and $T_{X \to Mil_X}$ will gradually become correlated as the agent-milieu interactions progressively bring forth a world where actions and perceptions are indeed correlated. Here also the meaning of $\Phi(X)$ becomes clearer: the more information is integrated in X, the sharper the filter it becomes for the information transferred through it. In other words, the higher the integration, the more the structure of X contributes to the correlation between its perceptions and actions.

Contingency and Innovation

The metaphysical principle of self-organization gives a critical role to random processes in bringing forth actual order out of non-order and sense out of non-sense. That there is in existence an inherent tendency to organize spontaneously, stands in sharp contrast to the second law of thermodynamics stating that systems will tend to increase their entropy till they reach a state of maximum entropy which in information theoretic terms means that all states are equiprobable, i.e., no organization. Yet, the notion of maximum entropy assumes a closed system that in the terms developed in the first part of the thesis would mean that difference is bound. We do not see any good enough reason to warrant such assumption on a universal scale. The development of this thesis explores the idea of open-ended systems and unbound difference.

It is still far from intuitive how disorder brings forth order. This is why till the advent of modern evolution theory, the common understanding of order needed a higher, godly or esoteric first principle as an explanatory anchor accounting for all the order apparent in existence. But even today the debate is going on as to whether the combined effects of random contingent change and natural selection are sufficient to account for the emergence of form in all dimensions.

What is it about existence that allows innovation – the seemingly inexhaustible emergence of new order and significance through the individuation of actual entities? In other words, how do stable forms and recurrent behaviours arise from unbound differences? Population thinking and assemblage theory are suggested as a framework of articulating individuation – the progressive determination of actual individuals in terms of distributed processes that manifest combinatorial productivity. At the most fundamental level it is the open-ended encounter between elements affecting and being affected by each other in the course of their interactions that is the abstract mechanism driving determination. It has been shown that populations of interacting heterogeneous elements may, plausibly, spontaneously bring forth more complex elements and recursively stratify (see also about interactions ahead), eventually producing open-ended innovation even without guidance. In order to gain further credibility this proposition needs further examination of a number of its problematic aspects.

Unbound Expression

Is actual existence infinitely creative? Are there no bounds to expression? Many individual expressions may be merely cases of repetition of the same Idea. The real question is therefore about innovation – the actual expression of new Ideas never expressed before. The question can be analysed in terms of assemblages. Clearly the variety of structure (the material aspect of assemblages) implied by combinatorial productivity is unbound. But we cannot assume that the relation of structure to expression is isomorphic. A single structure may have multiple expressions depending on the other individuals it interacts with. But it is also the case that different structures may have the same expression. We cannot therefore trivially derive the unboundedness of expression from unbounded combinatorial productivity of structure. Is it the case that unbound heterogeneity of structure nevertheless implies unbound richness of innovative expression?

Expression is the sense an assemblage makes as a whole to all other individuals in its milieu. It is how it affects them. In this sense, expression is the production of structurally dependent behaviour. An assemblage produces affects (acting upon its milieu) in response to perturbations it undergoes and in accordance to rules embedded in its structure. These rules originate from the nature of the elements that constitute the assemblage and their respective interactions. One way to study the relation between expression and structure is to relate to expression as an outcome of a computation. The computation is carried out by the structure as a computing element actively operating the rules intrinsic to it (e.g., for physical structures these would be the laws of physics, for economical structures these would be the rules of the market etc.), and where the ongoing perturbations are the inputs to the computation being interpreted in terms of the rules embedded in the structure.

Wolfram develops a hypothesis – the principle of computational equivalence – that bears on our case. The principle claims that "almost all processes that are not obviously simple can be viewed as computations of equivalent sophistication." By "obviously simple" Wolfram means any process for which a compressed description can be readily found. The principle asserts that in computational terms very simple computing processes can and do perform computations as complex and as sophisticated as arbitrarily complex computing processes. In the terminology of assemblage theory, if this hypothesis is correct (and it seems that it is), relatively simple assemblages may produce arbitrarily complex expressions. What this hypothesis means for our case is that even under simplifying assumptions, the potential wealth and variety of expressions is not bound.

Innovation in Populations

Highlighting the combinatorial nature of assemblages, we can address another question regarding innovation. In this model, innovation amounts to finding novel expressions by introducing random structural changes. But these are not easy to find. We can safely assume that the number of different expressions relevant in their milieu is only a vanishingly small fraction of the number of different structures. In the case of enactive systemic cognition, only a vanishingly small fraction of all assemblages may yield autonomous closures in their interactions. Searching for such assemblages is like trying to find a needle in a haystack. How could one expect to find anything interesting within a reasonable time frame relying solely on contingent perturbations that introduce random changes in the structure of assemblages? Common sense would support the view that the emergence of complex structures based solely on contingency and blind trial and error would take a prohibitively long time to happen, if at all. Furthermore, even if a complex assemblage with a significant expression had somehow individuated, it is very likely that random changes to its structure will destroy it and very unlikely that such changes will produce another innovative expression.

Wagner constructs an argument that shows how combinatorial productivity, i.e., random walks in structural possibility space, may yield, under certain general assumptions, innovation within a plausible time frame. The argument is adjusted and extended to our case based on two observations: the first is that it is possible to describe individuals as populations of assemblages in terms of their structure and expression. The second observation is that the properties of structures instrumental to the argument are based on relatively simple and context-independent graph-theoretic derivations.

The bottom line of the argument is that given a large enough heterogeneous population of assemblages and assuming that the population is allowed a sufficient period of natural drift (i.e., changing structure without changing expression), all subsets of assemblages having diverse structures but the same expression will be spread over the whole possibility space. This means that a vast repertoire of innovative expressions is accessible to the population and can be effectively explored all across the possibility space and under the selective constraints present in the milieu. The combination of heterogeneity and distributiveness makes innovation driven by random changes more plausible than what is intuitively grasped.

Innovation Spaces

A population of an entirely new kind of assemblages embodies a new space of innovation. Every such population is characterized by a set of individual building blocks capable of combining to produce large numbers of almost arbitrarily large assemblages. The combinatorial mechanisms are often (but not always) simple and uniform, that is, each element connects to other elements in the same manner (e.g., forming chains of elements), or follows a small number of relatively simple options (e.g., the case of atoms). These conditions also correspond to the emergence of a new coding system. In all cases, though, the formation of assemblages must be reasonably probable and the supply of the material elements abundant. These conditions are necessary for the formation and further development of such populations.

Apparently, the emergence of a new innovation space is singular, serendipitous, disruptive and rare. The characteristics of the already known instances of such spaces contribute very little, if anything at all, to predicting a future occurrence. Such events can be identified and characterized only in retrospect, since their occurrence does not seem to follow a single general mechanism or principle. In the light of the metaphysical framework developed in this work, the unexpected should be expected because thought and cognition in their broad sense are open-ended and there will always be events that break through the boundaries of what is known and what already exists, within established innovation spaces.

Interactions

Interactions have a profound role in bringing forth individuals, in determining actual properties and in realizing the inherent tendency of certain systems to self-organize and spontaneously manifest in distinct and relatively stable objects and relations. By interaction we mean a sequence of actions exchanged among agents that is initiated by an agent and unfolds in a chain of effects that returns, eventually, to affect its point of origination through at least one path. All agents connected along a closed path of activation necessarily interact with each other. Within such closed paths of activities, serendipitous exchanges may organize into persistent systems of interacting individuals. Interactions are the subject matter of cybernetics.

Complex Adaptive Systems (CAS)

The combination of population thinking and cybernetic interactivity gives rise to the concept of Complex Adaptive Systems (CAS). A CAS is a heterogeneous population of interacting entities called agents. The activities of CAS are distributed and asynchronous as agents are continuously adapting their own behaviours to changing circumstances caused by the behaviours of other agents. Adaptive behaviour normally implies a certain set of criteria or values to be optimized or held invariant, but adaptation can in many cases be nothing more than some correlated responsiveness. The general characteristics of CAS derive primarily from the nature of the agents considered (given in terms of their properties, behaviours and capacities to interact), the size of the population, its distributiveness, connectivity and heterogeneity.

A CAS is not a system in the classical sense because there is no global organization, goal, or principle guiding the activities of CAS. Neither the characteristics of the agents nor the topology implied by their interactions is presumed. The number of agents, their properties, behaviours and interconnections are all variable and often unpredictable. As a whole, CAS are capable of presenting complex and sometimes creative global behaviours.

In the terminology developed in this work, CAS are fields of individuation. With this description in mind, agents and interactions are assigned only the minimal representation required to describe processes of individuation. They are didactically described within a specific stratum along with its two adjacent strata: the substratum where the agents of the stratum are themselves undergoing individuation and the superstratum where the individuated assemblages of the stratum operate and interact as higher level agents. Every stratum delimits a plane of activity given to observation within a larger and theoretically unbound field of individuation. Within their stratum, agents interact and form assemblages. Assemblages individuate, form boundaries and eventually become integrated agents of a higher stratum. This activity may develop recursively across many strata and form hierarchies of agents and interactions.

Reciprocal Selection and Determination

In the context of evolutionary dynamics, the concept of adaptation has an obvious meaning: the modification of structure and behaviour of the organism for the purpose of increasing the probability of survival and procreation, that is, increasing fitness. Earlier, similar reasoning was deployed to explain cognition as an adaptive regulative activity facilitating the continuation of autonomy. It is easy to address adaptation as a kind of a purposeful activity of an agent towards the goal of ensuring continuity.

It follows that the story of adaptive behaviour is based on an already formed agent with certain properties and capacities, prominent among which is an express bias towards existence. In the more general case of CAS as a field of individuation, an obvious question is how agents come into existence in the first place. Furthermore, in cases where the maintenance of individuality is passive, purposeful adaptive behaviour is not obviously demonstrable. If CAS are fields of individuation we need to address adaptivity in a broader sense that will account for how agents individuate via reciprocally determining interactions.

Spontaneous Emergence of Reciprocal Selection

It is argued that even in the case of random interactions in heterogeneous populations of primitive agents, one can expect reciprocal selection and mutual determination of behaviours among agents towards the individuation of more complex and diverse agents. This can be demonstrated with a simple though somewhat involved example. It supports the claim that even prior to the emergence of complex adaptive individuals, and before adaptive behaviour as such is demonstrable, CAS are already fields of individuation and emergent complexity.

The example involves a population of agents and a repertoire of signals. Each agent is defined by a simple IF/THEN rule table that maps every input signal from the repertoire to an output signal. Agents can randomly connect and thus enter into interactions forming compound agents of two or more primitive agents. Even with such a highly simplified scenario of CAS (no adaptation is possible), a population of randomly assembled interactive configurations presents significant organization and richness of behaviour. By merely interacting, agents are selecting each other's behaviours. This is true since the output of one agent determines the rule that will be applied by the agent fed by it. With these reciprocal selections, the behaviours of the involved agents become constrained and correlated to each other. The local reciprocal selections do possess a clear global selective and organizing effect that is observable at the population level in the nature of signal sequences being produced.

By adding to the population another two components that allow the formation of slightly more complex topological configurations, even primitive state machines can be demonstrated to arise spontaneously (see specific details 9.3.1).

Equilibrium and Reciprocal Selection

In the classical cybernetic literature the idea of adaptive behaviour is based on the concept of equilibrium. The general assumption is that dynamic systems would tend to reach a final state called equilibrium or rest. On the condition that they are finite (in the number of component agents) and closed (no exchange of energy with the environment), all systems will eventually tend to a state of rest or at least to a state where some essential variables reach a state of invariance. In equilibrium, a system-defined quantity analogous to energy in physical systems is distributed more or less equally among its components so that any change of state will require an investment of energy external to the system. Systems capable of reaching equilibrium must be interactive, and this implies a mechanism of reciprocal selection between components or agents. The fact that a system must be closed or isolated means that all its agents' outputs are redirected to its agents' inputs. Under such conditions, there must be at least one closed loop of activations in the system, that is, an interaction as defined earlier.

The phenomenon of interaction and reciprocal selection can also be applied to open-ended systems where global equilibrium is not ensured and cannot be assumed. The open-ended case is never total; it would mean no interactions and therefore no invariance and no structure could actually persist because invariance and recurrence seem to be the product of interactions. Even in open systems there is spontaneous formation of recurrent patterns and structures. These might be fleeting but are nevertheless persistent for a while. Agents can become more or less individuated even without ever reaching final stability, or reaching stability for limited yet long enough periods to produce a sign, leave a trace and make sense to something other than themselves. The notion of stability itself becomes relational because there is no such thing as absolute constancy. This is why the state of affairs of CAS in general is best described as metastable: temporary islands of permanence within a vast ocean of impermanence.

The Temporal Aspect of Reciprocal Selection

The temporal aspect of reciprocal selection can be studied by applying the idea of structural coupling. To get an intuition of how structural coupling works consider a CAS where agents are described as state machines. States can be understood as primitive experiences or 'memories', each prescribing a different behaviour given the same trigger signals. State machines introduce an explicit temporal dimension to the activities of agents and their interactions in the form of their discrete state transitions. The present behaviour of an agent can depend not only on the input signal presently perturbing it but also on previous states and inputs. Structural coupling is realized as the interactions among agents introduce in each long term structural changes manifesting in their behaviours. With state machines we can formalize the selection of non-trivial behaviours and its historical unfoldment.

A general state machine may contain subsets of states with the property that once any of the subset member states is reached, all the subsequent transitions, whatever the input signals are, will only be among the members of the subset. Such subsets are termed attractor sets or closures. Closures may be contained within closures. Moreover, closures can be signal specific, that is, they are maintained only under the condition that signals present at the input belong to a specific subset of all the signals. With such generalization, closures can be entered and escaped from, depending on the sequences of input signals.

A closure within a larger state machine can be thought of as a reduced state machine with less memory and less variations on its rules. The signal(s) that cause a transition of the state machine into any one of its closures is selecting a more restrictive regimen of possible behaviours in subsequent perturbations and therefore make the agent more individuated. An agent can transit from a more individuated phase to a less individuated phase by escaping closures. The dynamics within a closure always involve recurrent state transitions if they continue long enough. The limited number of states and limited number of signals can combine to produce complex recurrent behaviours. Moving into, out of, and among closures, agents undergo phases of more or less stable behaviours and more or less determined behaviours. Signals can trigger phase transitions and actual behaviour changes of agents. With agents modelled as state machines, a vast repertoire of behaviours can be generated, including recurrent patterns of any length, pseudo random patterns, and any combination thereof.

Considering CAS as a population of agents modelled as state machines, agents become coupled by forming networks and exchanging signals. In CAS dynamics, subsets of states belonging to different connected agents can form joint closures. Such joint closures are in fact state machines emerging in the course of ongoing interactions between two or more agents. The behavioural patterns produced by such joint state machines represent coordinated activities among the agents but can also further individuate and become more distinct from the agents that initially produced them. This is how boundaries among agents may reform. Notice also that state machines emerging in the course of interactions clearly correspond to how enactive cognition and the 'bringing forth of a world' were described earlier.

Zooming out from this level of detailing, as the actions of the agents intervene in each other's ongoing structural transformations, they each become an influence on the other's individuation so eventually they individuate jointly. Remarkably, joint individuation does not predict that the two (or more) agents become one integrated agent or remain distinct from each other. This will depend on the specific nature of the interactions.

Historical Depth

The state machine model suffers from a major weakness to do with the *a priori* limits placed on the individuation of agents and their interactions by the characteristics of their representation. Originally, CAS were always modelled in terms of immobilized representations and realistically there is almost no escape from that. But for the full picture of CAS as fields of individuation, we need to keep in mind that sufficiently complex agents and situations have an internal mobile continuum – a duration that cannot be rendered in symbolic descriptions without losing something significant, if not critical, of their motion of becoming.

In dynamic systems we become well aware that in many systems certain behaviours (developing trajectories) become ultimately unpredictable because their evolution is infinitely sensitive to their initial conditions. In such systems, trajectories that are infinitely close at one point in time may diverge radically and unpredictably, which means radically different behaviours. We can understand such phenomena in terms of the system's memory. It can be said that the system possesses infinitely acute memory as to where it came from. Such memory cannot possibly be represented as discrete. Any two discrete points, no matter how close, contain an infinite number of critical differences of information as to future development. In other words, no boundaries can be placed to distinguish in such memory categories, events, episodes etc. It is exactly the kind of memory termed duration by Bergson. The historical depth of interactions operates as duration – an indivisible record that in many cases critically influences the individuation of agents but cannot be represented by the kinds of discrete models discussed earlier.

Agents with historical depth affect each other in a manner intrinsic to their historical depth and not only in relation to some discrete structural aspects. This exposes a deeper level of interaction where reciprocal selection actually means the mutual selection of ultimately unique trajectories, thereby producing unique individuated agents with regular behaviours only in the statistical sense, which always leaves space for unprecedented and unpredictable surprises. These rare surprise behaviours are one of the marks of realistic CAS. Understanding the impact of historical depth brings to attention interactive processes that cannot be modelled or simulated not only in practice but also in principle. Certain individuations remain ultimately unknown until they are actually determined and the outcome of such determinations has no precedence, computable approximation, or inferential basis.

Signals and Significance

Interactions are not communication, only an exchange of signals. Signals communicate only if and when they signify something of relevance for the agents that are the source and receiving ends of the signal. Signification arises when signals are contracted into signs. Even then, an exchanged signal may still signify different things to the transmitting and receiving agents. In the extreme case, the signs transmitted by one agent cannot be interpreted at all by the other. This situation is termed disparateness. The capacity to acquire signs develops in a process of individuation. Only in the course of individuation is disparateness resolved and the exchange of signals becomes an exchange of signs. Sense-making – the bringing forth of sense out of non-sense is another name for such a process. When the interactive operations of agents become coordinated exchanges of signs, it can be said that the agents have established a form of communication. All coordination can be traced back to the individuation of communication.

Complex signal-signs systems are of course nested. In the same way that the individuation of agents is stratified, so the individuation of communication systems among them undergoes stratified development complementary to the development of agents. The signs individuated at a certain stratum become signals in the superstratum concurrently with the agents that exchange these signs/signals.

Cybernetics, the Science of Interaction

Though etymologically the word cybernetics derives from the Greek $\kappa\upsilon\beta\epsilon\rho\nu\eta\tau\eta\zeta$ which means 'governance' and 'steering', cybernetics is first and foremost the science of interaction and communication. It is indeed an historical fact that cybernetics was, more than anything else, associated with control rather than communication but the categorical asymmetry implied by the word 'control' between 'controller' and 'controlled' is misleading and seriously narrows the profound scope of the concept. Roy Ascott's definition of cybernetics as "[t]he art of interaction in dynamic systems", indicates that cybernetics exceeds what can be safely designated as scientific in the same sense that thought sans image exceeds symbolic representation. It has already been argued that if there is something rather than nothing (and without presuming the first) it is only on account of interactions. From this perspective, the most inclusive definition of cybernetics is the science of becoming through interaction.

Feedback

Feedback is the most basic and straightforward species of interaction. It is best understood in terms of the concept of variety developed by Ashby. In simple terms variety is the number of distinct behaviours an agent may display, or the number of distinct signals a source of communication can produce. Variety can be quantified as the informational entropy associated with the repertoire of behaviours or signals and depends also on their relative probabilities. It is easy to show that maximum entropy and variety is achieved if all the behaviours or signals in a given repertoire are equiprobable.

The important properties of feedback can be demonstrated in the simplest case of two agents feeding each other in a closed loop. Every signal passing through the loop undergoes a recursive transformation, which is a product of the transformations of the individual agents in the loop. The whole power and significance of feedback lies in the recursive application of transformations. The features of the conjoined transformations in the loop determine the effect of the feedback as a whole.

If the conjoined transformations cause the variety of signals passing through the loop to converge to a value smaller than the initial variety, the feedback is considered negative feedback. If the variety converges to zero, the whole system converges to equilibrium and will display a constant behaviour. Moreover, because of the tendency of the loop as a whole to reduce variety, if a disturbance is introduced anywhere along the loop, i.e., one of the signals is displaced from its equilibrium value (or the variety of a set of signals at some point along the loops changes), the overall dynamics of the loop will resist the change and subsequent transformations will work towards returning the system to its equilibrium state. Resistance to change is perhaps the most significant feature of negative feedback and forms the most apparent link between interaction and the stability of individuals. In the more general cases, reduction in variety nevertheless means that signals become more predictable and making an agent or a process produce predictable behaviours is the very definition of control.

If the conjoined transformations cause the variety of signals passing through the loop to diverge, the feedback is considered positive. In positive feedback the variety goes to infinity, which means, putting aside practical considerations, that the whole system loses every distinctive property or limit on its behaviour; in other words it loses all individuation and disintegrates into random noise. Practically this never happens.

In the cases where the variety does not converge to zero and/or disturbances external to the loop are present, interactions may behave in a much more complex manner which will involve alternation between the negative and positive feedback regimes. These are the behaviours associated with metastability. The variety of behaviours or signals may both decrease or increase and the system becomes respectively more or less individuated. Complex configurations with multiple interactions may display a host of behaviours with combined positive and negative feedback loops and multiple equilibrium points. Notice that the interplay of positive and negative feedback in interactions provides the full range of evolutionary dynamics. While positive feedback provides increased variation, negative feedback provides selection and retention (i.e., resisting change in equilibrium states).

Reentry

How do interactive networks form? The formation of interactive loops requires not only that agents will be topologically related, i.e., in some relation of effective neighbourhood, sharing a medium or specific transmission channels among them, but also that their reciprocal actions will be somehow coordinated or synchronized without an *a priori* existing coordination mechanism. We hypothesize that diversity in populations of agents could provide an answer to both requirements.

If a population is diverse enough (see 8.1), agents presenting the same behaviour can be structured very differently and therefore the presence of certain behaviours or signals will not be bound to specific localities within the population. Every neighbourhood of agents within the population will tend to exhibit a wide range of behaviours and every behaviour will be present in almost every neighbourhood. Such uniform topological distribution is favourable in terms of the probability of spontaneous formation of interactions. A similar consideration can be made in regard to temporally coordinating the signals of agents. A diversity of timings permits the reciprocal selection of synchronized signals and behaviours, thus permitting the formation of synchronized interactions with probability correlative to the diversity of timings. The idea that complex coordinated interactions can initially arise from random connections is inspired by Gerald Edelman's theory of neural Darwinism and the mechanism of reentry.

The mechanism behind the theory of neural Darwinism relies on populations that provide diversity, a reciprocal selective mechanism (in this case phase locking of neural activation signals), and a retention mechanism (having to do with the preservation of frequently active synapses). We conjecture that a similar but generalized evolutionary mechanism can be responsible for the formation of synchronized interactions in many examples of CAS. At first sight, reentry is not a mechanism that would easily fit into the category of cybernetic feedback mechanisms. But a deeper examination will expose it as a variant of negative feedback loop where each agent in the loop is itself a population of agents presenting a diversity of timings and where the variety being reduced is the variety of timings.

Reentry provides an additional dimension of freedom (and complexity) in the formation of interactions. Instead of considering the interaction of specific agents that affect and are affected in specific ways, interaction can now be understood as interaction between populations. In such cases, the interaction loops are dynamic and particular agents join or leave the actual interaction on an ongoing basis while at the population level interaction is continuously sustained.

Stigmergy – Mediated Interaction

One cannot fully appreciate the organizing power of interactions without attending to an even less constrained kind of interaction – stigmergic interaction. The idea of stigmergy is that the actions of agents leave traces (deliberately or not) in the medium where the actions are performed. These traces serve as cues that guide and select the future actions of other agents, including those of the original one. With stigmergy, complex sequences of actions can be coordinated and organized without *a priori* planning, control or direct interaction or communication among the agents performing the actions. Moreover, stigmergy in most cases is agnostic in regard to the agent(s) performing the actions. It can perform in the context of populations as well as small groups of individual agents.

The efficacy of stigmergic mechanisms is based on a simple underlying computational paradigm: the medium is a memory. It remembers the history of the actions that happened and from which future actions are induced. The active agents are performing very primitive 'computations', which in most cases amount to 'writing' the memory by leaving traces, and 'reading' from the memory by being triggered to act according to a simple fixed rule(s) corresponding to the trace they read. The power of stigmergy as a coordination mechanism arises therefore from it being an asynchronous distributed computing paradigm. As a coordination mechanism, stigmergy is more effective in the sequencing and topological organization (relational locations of activities) of actions. It is less effective in synchronizing actions because in the general case the trace only affects the probabilities of consequent actions not their actual execution.

The significance of stigmergy lies primarily in the facilitation of complex interactions. Unmediated interactions require agents to form interactive loops. The probability of incidence of unmediated interactions will decrease and usually quite fast in proportion to the number of involved agents. But this is far from being the case if a population of agents is sharing a medium that allows them to affect each other without ever physically meeting. The frequency of certain types of traces and their spatial distribution guide the frequency and spatial distribution of subsequent actions. It seems therefore that the combination of an heterogeneous population and a shared medium is a very powerful yet non-specific catalyst to the formation of interactive loops and to the self-organization of complex patterns. Instead of having a population of agents that need to connect in certain specific manners to form interactions, there is a population of agents and a complementary population of traces that they leave on the medium. Agents from the first population act in parallel and collectively change the distribution of the population of traces. The population of traces, in turn, collectively guides the distribution of subsequent actions that will be performed by the agents.

This description of the stigmergic mechanism exposes that in fact stigmergy is a meta-level interaction between populations – the population of agents and the population of traces. This meta-level interaction is underlaid by a third population of specific interactions, where each instance is either of the form $Agent \rightarrow Trace \rightarrow Agent'$ or equivalently of the form $Trace \rightarrow Agent \rightarrow Trace'$. The incidence of specific interactions has a dynamic probability distribution. The population of interactions can be said to be constituted of virtual loops of interaction that make sense only in the context of the other two populations. The particular agents that actually constitute such interactions never connect. They only express patterns of activity that can be shown to have a tendency to persist only at the population level. The agents that fleetingly participate in these population-level interactions cannot be identified with them. When the population of agents and the population of traces are themselves viewed as interacting individuals, the way they affect each other is expressed by another individual (or individuating entity): the population of virtual interactive loops just mentioned. This individual is only identified by statistical quantities that are either derived directly from the corresponding population, or inferred from the statistical characteristics of the populations of agents and traces. It is conjectured that CAS are proliferate fields of individuation in large part due to such stigmergic mechanisms.

The Open-Ended Intelligence of CAS

It has been shown how patterns of structure and behaviour may start individuating via merely contingent interactions without assuming any *a priori* planning, design, guiding principle etc. These bootstrapping processes are especially significant in the context of this work because it is they that facilitate what was termed unsupported thought – the bringing forth of sense out of non-sense. Once populations of stable individuals and behaviours emerge, they become the building blocks of further individuations and of highly complex interactive systems capable (to different degrees) of passively or actively resisting change. The latter case is the definitional mark of adaptive behaviours in CAS.

What must be emphasized is the fundamental incompleteness of everything already individuated and thus already given to representation. There is a level of complexity altogether more profound that exists in the becoming of such individual systems. Individuation belongs to a regime of processes that cannot admit either already given rules or final equilibrium states that require closed systems. We believe that we have made the case that the cybernetic rationale behind interactions is powerful enough to account for individuation even without the constraints of isolated systems and fixed rules and without ever achieving global equilibrium. Even after a CAS has established, through many bottom-up developments, complex networks of interacting individuals, and even after adaptive goal-directed agents have emerged, contingent and totally unpredictable interactions are and always will be part of the dynamics of further individuations. Contingency keeps on playing a significant, if not critical, role in the bringing forth of the world at all scales. The impermanence of what *is*, is the only *a priori* that we need to admit.

CAS are actual fields of individuation and as such they are thinking cognitive systems. No matter how rudimentary or complex agents initially are, as long as they engage in interactions, and as long as sizeable heterogeneous populations of agents exist, CAS may bring forth novel objects, relations and behaviours. In other words, Ideas in the course of being thought. Though it is already implied by various associations of terms and concepts developed earlier, it has not been argued explicitly that CAS are intelligent. Indeed it is argued that CAS are concretely and actually intelligent but not in the same sense that the concept intelligence is commonly understood. Intelligence is normally associated with purposeful, predictive and adaptive behaviours. More than anything else intelligence is associated with maximizing the performance in achieving given tasks under constraints, the achievement of goals (e.g., maintaining complex equilibrium states) and with problem-solving in general. These intelligent manifestations are already individuated products. The intelligence manifested by CAS is productive. It is neither purposeful nor predictive; at least not globally. It would rather be described as experimental and open-ended.

By open-ended, we mean creative and fundamentally unpredictable in regard to outcomes. Ironically, it is called blind (like natural selection is blind) as if it is merely about random choices of already existing possibilities. But the possibilities being selected are not there prior to the selection; they only seem to have existed in retrospect as if the maximization of some utility function was guiding their selection. The individuation of an organ, a whole organism, a society or a worldview is not about blind selections but rather about how selections come to fit and cohere together in an ongoing interactive process of selection (previously termed transduction). Agents brought into interaction in CAS are brought into a problematic situation where each continuously disturbs the others by merely affecting them, causing them to change and consequently disturb other agents. In the course of interaction the agents resolve the problematic situation by reciprocally selecting and progressively coordinating their respective behaviours. This process can initially be based on pure trial and error but gradually becomes (locally) guided as agents learn to associate their actions to disturbances (i.e., cognition) and respond adaptively. They cast a world of significance and become value driven. At all levels and scales of development, from the simplest to the most complex, the motion towards resolution of an ongoing problematic situation is the mark of open-ended intelligence.

Chapter 16

Conclusion

> We shall not cease from exploration
> and the end of all our exploring
> will be to come back
> to the place from which we came
> and know it for the first time.
>
> T.S. Eliot

Here is a non-conclusive story of difference and expression: The sufficient reason of all there is, is difference – virtual difference. All there is exists only as limits on the unfoldment of difference. It is difference itself which is self-limiting and by that brings forth actual expression – objects, subjects, relations, concepts, images, ideas, systems and potentialities. I have called this formative process open-ended intelligence. The claim of this story is not of truth but of significance. By significance I mean here the power to introduce change in the way one thinks and in the way one is. It is an experiment and exploration that naturally involves intensity and honest speculation of the kind that may make the *new* more accessible.

In the course of this work, open-ended intelligence is presented via a number of overlapping concepts: individuation, becoming, self-organization, thought sans image, cognition, and sense-making, each highlighting a palpable aspect in a complex event that does not give itself to definition per se. It is the nature of open-ended intelligence that it is a shy evanescent creature. It cannot be domesticated within a boundary and can only be glimpsed roaming the forbidden territories of the Aristotelian excluded middle. Once hunted and caught, it has already turned into something else. It has become the sensible, the thinkable, the recognizable and knowable. It nevertheless remains immanent in all these products, further animating their expression.

It was Varela who had already hinted at a deeper understanding of intelligence derived from his theory of enactive cognition:

> "The most significant innovation [of enactive cognition] is that since representations no longer play a central role, the role of the environment as a source of input recedes into the background. It now enters in explanations only on those occasions when systems undergo breakdowns or suffer events that cannot be satisfied by their structures. Accordingly,

> intelligence shifts from being the capacity to solve a problem to the capacity to enter into a shared world of significance." (Varela, Thompson, and Rosch, 1992, p. 207)

With open-ended intelligence, this innovation is taken a profound step further. Entering a shared world of significance is no one's capacity because both the environment and the agent, the object of cognition and its subject, are products of an underlying creative process that precedes both. There need be no *a priori* assumption as to the nature of either as the cognitive event unfolds into a shared world of significance. In bringing forth individuals and their relations, open-ended intelligence precedes and exceeds all specific forms and manifestations of intelligence. Evolutionary processes, mental-cognitive processes and general processes of self-organization are in fact different representational and explanatory regimes emerging from this overarching creative process.

As a concluding note I share in the following a number of thoughts first regarding directions of further research and application and then about how one might live in the light of the philosophical direction this work has taken.

16.1 Horizons of Open-Ended Intelligence

16.1.1 Science in the Light of Open-Ended Intelligence

Though it can be hardly stated that there is a single paradigm of how to practise science, there are a few operational principles that are common to all scientific programmes. Most critically perhaps is that all scientific thinking is based on representation. The object of scientific investigation must first be defined and immobilized in order to be representable. Practically, in order for this to happen the object must be isolated and placed, in as far as it is possible, in a controlled environment. The validation of any scientific theory is based on the reproducibility of observations under the specified controlled circumstances, and the predictive power of the theory in relation to certain outcomes is again tested under strictly controlled conditions. In these, and in many other discipline-specific practices and methods, the marriage between science and object-oriented identity-based metaphysics is undeniable. Arresting all differences except those which are prescribed is the primary method of ensuring the correspondence between the world and how it is represented in terms of identities and subjugated differences. Wherever the subject matter of investigation hardly gives itself to the general precepts of representation and duplication of results, or where it does but only at the cost of over-simplification and caricaturization, almost always the scientific credibility of the investigation will be questioned if not entirely dismissed.

There is no denying that the scientific paradigm is powerful and immensely successful. Yet its application comes at the price of marginalizing if not entirely excluding those kinds of phenomenon that do not fit it, e.g., complex irreducible phenomena that cannot be isolated, singular and rare events that can hardly be reproduced or predicted, phenomena whose historical depth and sensitivity to initial conditions cannot be eliminated or controlled, processes of individuation in general, etc. More generally, everything that does not fit and cannot be reasonably tamed to fit the image of thought as representation. In those cases where there is an attempt to apply the scientific paradigm to such phenomena, the practice is so complicated and expensive that progress becomes excruciatingly slow. A prominent example is brain research. Besides the obvious technical difficulties, living brains are complex mobile phenomena. Not only are no two brains made alike, but even a single brain differs from itself from moment to moment. There is a genuinely paradigmatic difficulty in addressing this mobility of brain structures with current scientific practices.

Admittedly, the problems involved are very difficult. But the question of whether some of these difficulties are rooted in the metaphysical ground underlying the foundations of scientific thinking is worth pursuing. As discussed in 6.4, 7.3 and other places under the designations of complexity thinking and open-ended intelligence, this research points towards directions of how the scientific method might be extended to embrace the kinds of phenomenon mentioned above and where the method itself might undergo individuation. Examples of experimenting with the very way scientific research is carried out can be observed in the so called *makers movement* (Chris, 2012) and in projects like *Foldit*[1] using a competitive computer game as an effective way to recruit, engage and organize ordinary citizens to help solve difficult scientific problems (Good and Su, 2011). Another example is the concept of personalized medicine. Recognizing that the human organism is far too complex and entangled, personalized medicine targets problems on an individual basis. It is becoming quite apparent that for complex conditions such as cancer, autoimmune diseases, mental conditions and such, there is no one cure that fits everybody. Treatments and cures must be tailored individually.

A more challenging research problem in the philosophy of science would be to develop a novel complementary scientific paradigm grounded in difference-based metaphysics instead of identity-based metaphysics. Developing and demonstrating such an alternative will yield a deeper understanding of what science beyond representation might mean and how it might be practised.

16.1.2 Life Sciences

The concept of evolution occupies a central place in this research. Both the metaphysical and systemic perspectives of individuation, it must be emphasized, go beyond evolution as a blind process of variation, selection and retention. Considering

[1] See: https://fold.it/portal/info/about

current and future horizons where the conceptual framework of open-ended intelligence can be incorporated into ongoing research programmes, two interesting areas of interest are worth mentioning. Both are to do with evolution.

16.1.2.1 Individuation in the RNA World

An example of a theoretical research that fits remarkably well into the conceptual framework developed in this work is the theory of viral quasispecies consortia to do with the theory of the RNA world as the beginning of life. In (Villarreal and Witzany, 2013, 2015), the authors develop a theory that describes and explains the contribution of viruses to the emergence of life and the evolution of life ever since. The authors hypothesize how single RNA stem-loops – molecules that operate solely by chemical laws – self-ligate to form consortia of cooperating stem-loop molecules in the context of which variation, selection and retention in the biological sense can be applied. In these molecular configurations, the authors argue, the evasive threshold between the non-living and the living is crossed.

The authors' point of departure is the theory of the evolution of viruses, central to which is the concept of quasispecies (Villarreal and Witzany, 2013, p. 80). The conventional concept of a quasispecies signifies a large group or a 'cloud' of related genotypes that exist in an environment of high mutation rates[2]. In our case, it is a cloud of self-replicating RNA molecules. The self-replicating entity is not an individual molecule but a cloud of variant reproductive molecules. The important point, however, is that within the so-called cloud there exists a type of master fittest molecule, which dictates the overall distribution of variants within the cloud and the ongoing reproductive dynamics according to the precepts of natural selection.

In the vocabulary developed in this work, this description is identity-centred (master fittest molecule), and other molecules (mutant spectra) in the quasispecies are merely errors in the reproduction of the master type. The authors argue, against this image, that variants within a quasispecies do not represent errors in relation to a fittest original but instead represent novelties that form together cooperative consortia, where fitness in the evolutionary sense can only be associated with the consortia as a whole.

In this scenario molecular variants are a multiplicity of interacting individual elements that reflect differences with no *a priori* identity. In the course of their interactions, they assemble to form what was termed in 7.2.4 fluid identities that retain inner coherency through cooperative interactions similar to closures but not necessarily strictly closed. Here is how the authors describe the individuation of complex structures within a population of interacting elements:

> "If numbers of stem-loops are able to build complex consortia with greater competence, they would then represent the initial cooperative interactions needed to develop living systems that are not present in a

[2] see: https://en.wikipedia.org/wiki/Quasispecies_model.

> strictly chemical world. The resulting system must function to maintain itself. In consortia, the emergence of identity (ability to differentiate self vs non-self) is a crucial initial step." (ibid., p. 81)

Additionally, the authors highlight the emergence of what was termed in 8.6.3 an innovation space at the beginning of life:

> "[T]hen the RNA population (quasispecies) can be considered as a "culture" that retains a common language which provides a level of group coherence (qs selection) on the basis of compatible cooperative organization. Each individual diverse RNA then becomes like a potentially new word for that language, i.e., new agent in the ensemble of interacting agents." (ibid., p. 84)

> "In no other natural language are the agents that communicate (coordinate and organize) via repertoire of natural signs (language) also identical with the signs (words) themselves. This is precisely what we have proposed with stem-loop RNAs. This proposition defines a new phenomenon: at the beginning of life agents and "words" (information) are identical." (ibid., p. 87)

There is a number of interesting parallels between this theory and the conceptual system developed in this work, e.g.:

- Multiplicities of differential elements without an 'original';
- A process of progressive co-determination via interactions within a quasispecies;
- The emergence of fluid identities;
- Stratified populations;
- The double aspect of structure and expression in individuals and the mechanism of transduction as current expression guide future expression by operating on current structures;
- The emergence of a coding system.

Here we see an area of research where our conceptual framework could significantly contribute to a deeper understanding of the formative processes involved. We also notice that the individuating cooperative interactions taking place within a quasispecies consortia, and which are manifestations of open-ended intelligence, precede the more familiar evolutionary process of natural selection that already presumes an agency undergoing evolution.

16.1.2.2 Beyond Darwinism

The problem of the source of innovation in evolution has consistently attracted increasing attention in the contemporary discourse about evolution theory. The triple mechanism of mutation – selection – retention at the foundation of Darwinian thinking is indeed extremely powerful and was demonstrated to have far reaching applications beyond the context of biology (Campbell, 1997; Dennett, 1995; Edelman, 1987; Gontier, 2006). It becomes clearer, however, that the explanatory power of Darwinian theory is mostly limited to accounting for smooth gradual changes and fails to explain more disruptive evolutionary events. Evolution, especially when it comes to radical innovations such as eukaryotic cells, multicellular organisms and novel body plans, seems to have employed additional mechanisms of producing innovation. Prominent among such mechanisms, which are gaining consensus as to their importance to evolution, are symbiogenesis (Gontier, 2007), niche construction and (to a lesser extent) exaptation (Andriani and Cohen, 2013; Kylafis and Loreau, 2011).

Briefly, symbiogenesis can be defined as "[. . .] the process whereby new entities are introduced because of the interactions between (different) previously independently existing entities. These interactions encompass horizontal merging and the new entities that emerge because of this are called symbionts. The process is irreversible and discontinuous." (Gontier, 2007, pp. 174-175). In the terms developed in this work, interaction and the formation of assemblages (see 9.3, 8.2) are foundational to symbiogenesis. The role of interaction is quite obvious but the experimental aspect inherent in assemblage formation and the concept of metastability provide a deeper understanding of the individuation of symbionts and the symbiotic systems they form.

Niche construction is to do with the impact (positive or negative) on the overall landscape of selective pressures caused by changes to the environment that are results of the organism's own activities. Niche theory claims that organisms guide their future evolution to a significant extent by changing their environment and consequently the selective pressures to which they are exposed. Note that the effects of niche construction on evolution depend only indirectly on the conventional mechanism of genetic inheritance of adaptive mutations. Future generations of organisms 'inherit' the modifications to the environment introduced by past generations. An extreme example of such a mechanism is of course human culture. Here again we find advantage in the conceptual framework developed in this work. Neither the organism nor its milieu can be said to have an *a priori* set identity. Niche construction is a process of individuation that involves both biotic and abiotic agents with metastable identities. The concept of systemic (enactive) cognition captures the idea of niche construction across a multitude of dimensions from the individuation of representative neuro-cognitive structures in brains (including the evolution of language as a means of structured interaction among organisms) to the projection of such structures back to the physical environment via the organism's interactions (e.g., building dams and nests, marking territories, agriculture, building roads, cities and technological artefacts etc.). At least in the case of human beings it is evident that the rate of innovation production (and its acceleration) achieved by niche construction far exceeds that which is possible by the Darwinian mechanisms alone.

Finally, the relatively more recent concept of exaptation, first suggested by Gould and Vrba (1982) is another innovation-producing mechanism not covered by Darwinian explanation but captured within the wider framework of open-ended intelligence. Exaptation is a process, or rather an event, where certain traits of a system evolved in response to certain circumstances but are later involved in carrying a function entirely different from their initial raison d'être, e.g., feathers that evolved for thermal isolation but later enabling flight. While adaptive mechanisms better explain gradual evolution, exaptation is differentiated by a relatively rapid co-opting of an already existing structure to a new function. Exaptation is naturally captured by assemblage theory and the understanding that experimental assemblages can bring forth radically novel expressions by recombining existing structural elements, especially when a population of elements is both heterogeneous and diverse (see 8.2, especially quote on page 187). Taking into consideration the creative potential of assemblages with the diversity of variations expected by evolution understood as natural drift (see 7.1.6), exaptation need not be a particularly rare event. Exaptation is not confined only to structures that present optimal adaptations. It actually works on a much larger population of 'good enough' adaptations that are candidates for innovative exaptation.

These examples are all interesting theories that can be argued to be derivatives or aspects of open-ended intelligence. Innovation beyond the classical evolution theory is where we see a promising horizon for application and further research. This prospect has already been highlighted by Deleuze and Guattari (1987, p. 258): "[...] becoming is not an evolution, at least not an evolution by descent and filiation [...] It concerns alliance. If evolution includes any veritable becomings, it is in the domain of *symbioses* that bring into play beings of totally different scales and kingdoms, with no possible filiations." (see also (Smith and Somers-Hall, 2012, pp. 252-254) for more details).

16.1.3 Open-Ended Intelligence and Consciousness

Consciousness may perhaps be one of the most significant examples of an ongoing process of individuation. Therefore consciousness study is a topic of research where open-ended intelligence is well positioned to provide additional conceptual tools and valuable insights.

One of the most obvious problems in consciousness study is the application of the deeply rooted epistemological dichotomy between subject and object and the kinds of knowledge associated with them (Gasparyan, 2016). Both subjective and objective perspectives on consciousness seemingly miss an essential aspect of what consciousness is. The metaphysical framework developed in the first part outlines an approach that precedes this pronounced dichotomy of the object and subject and can address the prior problem of its arising in the course of individuation. Dehaene (2014), for example, argues that what counts as genuine consciousness is conscious access to information, that is, the fact that certain informational structures enter awareness and become reportable. He claims that there is no fundamental distinction between the so called phenomenal consciousness and conscious access, the latter being "the gateway to more complex forms of consciousness" (pp. 22-23). If phenomenal consciousness is the sole territory of the subject, Dehaene's position can be understood as proposing that consciousness precedes the subject-object distinction, or in other words that this distinction is apparently a certain informational structure given to conscious access. Inasmuch as the scientific evidence is convincing, philosophically it boils down to the question of how well the dichotomy can be explained (or explained away) by deploying a scientific programme committed to objectivity. Still, others would argue that there is no way to address consciousness without admitting the primacy of phenomenal experience and its irreducibility to objective descriptions (Chalmers, 1996). This argument is verging dangerously towards substance dualism and therefore invokes quite a few difficult problems too. The point here is not about taking a side in this involved debate about the nature of consciousness but rather to indicate possible relevant avenues to address the problem in the light of the formative processes that bring consciousness forth.

Theories of consciousness that have already become mainstream such as the Global Workspace theory (Baars, Franklin, and Ramsoy, 2013; Baars, 1993), share their central motifs with processes of individuation. The idea common to these theories is that conscious content is a product of coalitions of specialized unconscious processes that compete and cooperate in order to temporarily take hold of a broadcast resource through which they globally broadcast information to all other specialized processes in a brain-wide scope. By so doing they also muster their specialized resources/competences towards a coherent response to a situation of high relevance and priority. The stream of consciousness is thus hypothesized to be the ongoing flow of such global broadcast events. Dehaene proposes a theory similar to that of Baars named "Global Neuronal Workspace", emphasizing the neural mechanisms involved in such a theory and their function of selecting, amplifying and propagating relevant thoughts (Dehaene, 2014, chap. 5). Edelman and Tononi (2000, chap. 12) offer yet another variation under the name "Dynamic Core Hypothesis" (also mentioned in (Weinbaum and Veitas, 2017) as an example of processes of individuation in the brain).

The conceptual framework developed in this work fits naturally with these theories. Consciousness can be understood as a global event taking place within a population of interacting individual agents that form and reform higher level individuals. The continuum of the stream of consciousness is constituted of interpenetrating individuated events, each of which is an assemblage of lower level neuronal processes (themselves undergoing individuation) that consolidates once a threshold of relevance is crossed. Once an assemblage consolidates and becomes temporarily stable, it then attracts massive participation and becomes global. Yet the glory of any such single event is fleeting in the course of an ongoing process of integration and disintegration.

Our framework invites thinking of consciousness not only as an organismic function in the service of adaptation and survival but also as a more profound modality of self-organization that also leads to the individuation of subjects and objects. Many of the identifying qualities of phenomenal consciousness are described within a framework of representation that must already assume a notion of an *a priori* subject or even selfhood (chapter 2). It seems to us that this is approach is philosophically problematic. Consciousness studies could therefore merit from an approach that allows formative non-representational processes and goes beyond strictly object-oriented ontology.

16.1.4 Artificial General Intelligence

The idea of intelligence going beyond representation has already a respectable history. Brooks (1991b) observed that with forms of intelligence manifesting in the ability of organisms "to move around in a dynamic environment, sensing the surroundings to a degree sufficient to achieve the necessary maintenance of life and reproduction", it might well be the case that representations and models of the world simply get in the way and "it would be better to use the world as its own model". He also made the interesting observation that "[t]his part of intelligence is where evolution has concentrated its time – it is much harder." In another paper Brooks (1991a) argues that the kind of intelligence involved in perception and physical mobility are a necessary basis for higher level intellect. In other words, Brooks proposes a theory of a bottom-up building of intelligence where the interactions between the agent and the environment are "determinants of the structure of its intelligence." These ideas were developed more or less in parallel with the emergence of the theory of enactive cognition described in chapter 7. Though Brooks' considerations were mainly pragmatic, focusing on building robotic systems that can effectively interact in the physical world, his deeper insights foreshadow the concept of open-ended intelligence:

> "It is hard to draw the line at what is intelligence, and what is environmental interaction. In a sense it does not really matter which is which, as all intelligent systems must be situated in some world or other if they are to be useful entities. The key idea from intelligence is: *Intelligence is determined by the dynamics of interaction with the world.* " (emphasis in the text) (ibid., p. 584)

At the conclusion he adds:

> "*Intelligence without Reason* can be read as a statement that intelligence is an emergent property of certain complex systems – it sometimes arises without an easily identifiable reason for arising." (Brooks, 1991a, p. 591)

The two major points captured here are the intimate connection between intelligence and interaction and, even more importantly, the understanding that intelligence itself undergoes individuation without an apparent final goal. Also worth mentioning is (Froese and Ziemke, 2009), dated almost two decades later, which presents an in-depth treatment of the philosophical and technical aspects of incorporating enactive cognition into artificial intelligence research.

The claims made about open-ended intelligence take a more radical view by highlighting it as a formative process and differentiating it from its products – the goal-oriented and problem-solving kinds of intelligence (Weinbaum and Veitas, 2016b). Open-ended intelligence is indeed how interactions come to express intelligence by bringing forth both agents and their environments. By this, we introduce a novel way of thinking about general intelligence and specifically how to approach artificial general intelligence in a manner which is unbound to *a priori* given agents, environments and goal-oriented thinking. The incorporation of open-ended intelligence into a more concrete research programme in artificial general intelligence is still preliminary and is a work in progress. It is clear, however, that general intelligence involves an ongoing dynamics of individuation, boundary formation and dissolution, and sense-making that are only partly guided by already given teleological or inductive precepts. We see one of the most promising prospects of open-ended intelligence in the further development of these ideas .

It is hardly deniable that the prospect of building artificial human-level intelligent systems invokes many concerns and is the subject of a growing public discourse. Central to such concerns is the possible scenario that artificial intelligent agents will become immensely more intelligent and capable than humans and consequently humans will lose control over such systems and will become marginalized if not extinct. Bostrom (2014) provides the most authoritative account to date of such concerns. Central to Bostrom's arguments is the understanding of general intelligence as goal-oriented. One category of scenarios involves autonomous artificial intelligent agents going rogue by forming and pursuing their own goals and interests that will not necessarily take into consideration the goals and interests of their human creators. A second category of scenarios involves such agents following goals prescribed by humans but radically misinterpreting the actual goal and inflicting as a result disastrous outcomes by merely trying to optimise their performance. In both scenarios, a sufficiently intelligent agent is speculated to be able to circumvent the limitations and safeguards installed by humans and will go out of control. This line of reasoning has become a leading theme in the way people think about the future prospects of artificial general intelligence. It fuels in the general public sentiments of aversion and fear towards a technology that may well be humanity's next breakthrough on myriad fronts if not a last resort in successfully addressing very complex problems at the planetary scale.

The concept of open-ended intelligence provides a powerful alternative to understanding intelligence. Goertzel (2015) analyses Bostrom's and other alarmist approaches towards the prospects of creating a super intelligence. He highlights the alternative open-ended intelligence may present:

> "Open-Ended Intelligence presents a starkly alternative perspective on intelligence, viewing it as centered not on reward maximization, but rather on complex self-organization and self-transcending development that occurs in close coupling with a complex environment that is also ongoingly self-organizing, in only partially knowable ways." (ibid.)

> "The theory of open-ended intelligence rejects the idea that real-world intelligent systems are fundamentally based on goals, rewards, or utility functions. It perceives these as sometimes-useful, but limited and ultimately somewhat sterile, descriptors of some aspects of what some intelligent systems do in some circumstances." (ibid.)

The manner in which humans understand intelligence has profound implications that go beyond scientific and technological prospects. This is because the very idea of super intelligence is related to the belief that human intelligence, being the highest known form of intelligence, is a threshold that also reflects on what intelligence in general is. Artificial super intelligence therefore is mostly understood as a quantitative extension of human intelligence and not as a qualitative one. Needless to say this is an anthropocentric view that only places a mirror that reflects certain aspects of human nature deeply rooted in biological imperatives, as already mentioned in the introduction.

We believe that open-ended intelligence provides an escape route from this kind of thinking towards an understanding of intelligence beyond the human condition. This involves not only the nature of prospective artificial intelligence systems and their relations with humankind, but also holds the potential for a prospective augmentation of human intelligence itself.

16.1.5 Social Cognitive Systems

Social cognitive systems, their development and dynamics are natural candidates for the application of the framework developed in this work. The individual, any individual, always exists between two strata: the substratum of individuals that constitute it and the superstratum of the individuals it constitutes (see 8.3). In (Combes and LaMarre, 2013, p. 24) Combes writes:

> "In effect, if we choose to describe the interior relation of the individual to itself as a relation between the individual and "subindividuals"

> that may enter into its composition, and if we do not forget that the living individual is also in a constituting relation to the group to which it belongs, that is, to a sort of natural community (society of ants, bees, etc.), we see that "The relation between the singular being and the group is the same as between the individual and subindividuals. In this sense, it is possible to say that, between the different hierarchic scales of the same individual and between the group and the individual, there exists a homogeneity of relation"" (the quote within the quote is Simondon's (Simondon, 2005, p. 160))

Social cognition can be studied on two different planes depending on the formulation of the research problem. The first is more straightforward and is to do with the individuation of social organizations as cognitive agents (e.g., corporations, governments, political parties, social networks, cultural movements etc.) in the human context, but also extends to the study of social insects, swarms, packs and other groups of animals. The second plane conceived by Simondon (ibid.) is more complex and addresses the relationships between individuations at different strata: the psychological individuation of human individuals and the individuation of the social bodies they participate in. Simondon posits a systemic unity between the two individuations which he terms the *transinidividual* (see (Combes and LaMarre, 2013, chap. 2)). This unity can be understood in terms of enactive cognition taking place in the social domain. The bringing forth of a social world by the interacting individuals that constitute it is definitely a collective individuating activity. De Jaegher and Di Paolo (2007) extend the concept of sense-making into the social domain and show how interactions among individuals may bring forth collective autonomies and social coordination.

There is a growing number of concrete research areas where distributed systemic cognition and open-ended intelligence applied to social structures can serve as a theoretical ground. Among these we can mention social networks, the internet of things, networks of coordinated autonomous agents (e.g., autonomous cars on the road), hybrid networks of human and machine agents, smart cities, smart governance and Global Brain scenarios (Heylighen, 2011, 2015; Veitas and Weinbaum, 2015).

16.2 How Might One Live?

Todd May's opening chapter to his book on Deleuze (May, 2005) is titled "How Might One Live?". I find this question an appropriate title to this work's final note firstly because it is formulated as a question. I started this project with a question about thought. The significance of the effort invested in this work, at least in the author's eyes, is in correlation to the extent to which it managed to invoke yet deeper questions. For thought in the form of a question is a catalyst for further becomings.

Secondly, I deeply resonate with replacing the classical *should* with *might*, transforming this perennial question from a search for prescriptive answers to an affirmation of indefinite possibilities.

In the light of this work, human life is an expression. It is an expression deeply conditioned by many strata of individuation, physical, biological, cultural, historical and, over these, additional layers of genetic make-up and personal experience that guide a person's future individuation. One, it seems, is always made of other things about which one has had little choice if any. Yet human individuals never stop individuating. Every individual has available to her indefinite lines of flight, to use Deleuzian terminology, breaking away from the prison of conditioned existence. These are virtual lines of becoming and possible transformation that extend from the actual here-now far into open horizons. They do not lead to anything that is already there waiting to be discovered. They are rather lines of development leading towards things-to-be-created in the becoming of one's expressed humanity.

Though it is indeed the case that many of the choices one makes, perhaps the majority of them, are constrained and therefore are not choices at all, it is also the case that here and there are singular turning points – choices that hide unforeseen and unpredictable opportunity. These are the loose ends of lines of flight tied by little or no constraint. These appear as hints of Ideas far from being clear or distinct, only minute cracks in the ongoing banality of everyday life. Finding these escape routes requires acute mindfulness and sense of wonder. Pursuing them to wherever they might lead requires fearlessness and curiosity. Weaving them into the fabric of one's life of immediacy requires the cultivation of joy beyond pleasure and pain. These are the marks of an experimental approach to life – the willingness to embark on paths that are not obvious, unrecognised and unsupported by sense, reasoning or experience.

Living life as an experiment is not merely a lifestyle choice. It is a metaphysical commitment to the primacy of difference over identity and of becoming over being. One's life gains meaning in as far as it facilitates the possibility of evolution, of growth and the overcoming of limits. Life lived as an experiment becomes an expression of open-ended intelligence. Style and aesthetics do mightily matter but these are not prescribed; they need to be figured out in the course of one's becoming. Life as an experiment is a thought experiment and an experiment in thinking. It is to think and let oneself be thought while not taking anything for granted; to be able to escape the banality of everything habitual in sense and thought. A real thought is real to the extent that it transforms the thinker. It might take a lifetime to give birth to a thought of such impact that it transforms the thinker from her very roots. Conceiving such a thought and bringing it to its full vital expression, making it the drama of one's life and a celebration of Life, is how one might live.

What would living life as an experiment entail? Experiments are conventionally understood in terms of success or failure against certain goals, expectations, beliefs, predictions etc. This is far from the sense of experiment as meant here. This is not to say that success or failure cannot be attributed to events of significance. Sometimes these are fateful turning points in one's life for better or worse. Yet the radical meaning of experiment goes beyond these. Living life as an experiment is an ongoing affirmation of openness. Life passes through ups and downs, troughs and crests, local deaths and rebirths, yet intrinsic to all these phases is the inner intensities that are their undoing. Living life as an experiment is to live an open-ended life – to embrace both the moment and its undoing, the being and the becoming. It is indeed the case, both metaphysically and actually, that the very root of existence is resisting change. It is a physical, biological and psychological imperative; otherwise nothing could ever exist. The very idea of 'I', of selfhood, of being someone is resisting change. But instead of putting selfhood as given at the beginning of one's being and living life as a continuous struggle against whatever comes to change it, one can put selfhood as a horizon and live life as a never-ending self-creation. Instead of cultivating an identity one could cultivate a fluid identity.

People are conditioned and educated to believe they are someone and are entitled to assert their identity and fully express it (and there are myriad precepts, philosophies and traditions of how this should be rightly done). To live life as an experiment means to release this belief in permanent selfhood and the immediate imperatives it entails. Being someone will necessarily force one to claim a closed boundary between 'me' and 'other', 'us' and 'them', 'for us' and 'against us'. Is it not the source of all human misery? Being no one – born of difference – is all-affirming because at core all beings are different yet interconnected and meant as beings in the same sense (see 4.1.1). There can be no ultimately closed boundary, no final separation. Being no one is not a negation of selfhood, as it is all too often misunderstood. Being no one, one can still be oneself, one can certainly become, but one is released from any notion of *self-importance*. One can find no support in being no one. It is therefore a nomadic existence without the safety of the permanent settlement identity offers. It is a demanding existence, for one must be ready to meet the unknown, moment by moment, and reassert responsibility for that which is expressed by one's choices.

An obvious objection under the guise of consent would be to argue along the lines of: "But of course, mine is a fluid identity by definition. I keep on adapting to changing circumstances maintaining my autonomy and uniqueness as an individual…" But adaptation does not amount to living life as an experiment. Even a certain measure of experimenting within safe boundaries is not enough. To experiment with one's being means taking certain risks in challenging one's own bases of identity. The cultivation of a fluid identity goes beyond psychological adaptation and flexibility. It requires a fundamental non-familiarity towards oneself, a readiness to meet the stranger in oneself and embrace it. It means a joyful accommodation of otherness, even radical otherness, and through that becoming open to the 'Other' per se. Whether it is a human being different from me, a worldview or a culture I do not understand, another lifeform, or another desire to be, these are all expressions of the different. Yet nothing is far enough or different enough from me if I am able to relate to it, even if relating means aversion. The 'Other' underlies all these. It is that which is unsupported by my experience and self-image, and yet deeper, that which is unsupported by anyone's experience. It is beyond the limits of sense thus forcing one to think/become the *New*. It is via the other that one can evolve. The limits of one's evolution are therefore the limits of one's accommodation of otherness. It is the difference, the intensity brought to the surface of expression while interacting with the other that is the transformative mover. It almost always comes along with a sense of fatality and danger but also with irresistible attraction – a vital trembling and playful spirit, a longing for far unexplored places, which seem to have been lost from modern lore.

All this of course begs the question whether life as an experiment means that everything goes? Does openness mean to be open for all always? This is certainly not what experiment means, though at the extreme margins there is always the danger of getting lost in such thought. Openness must not be confused with extreme relativism. Openness without selection is meaningless since thought – the expression of virtual Ideas – must involve progressive determinations via interactions with other individuals. It was already clarified that the distinct expression of certain Ideas necessarily excludes the expression of other Ideas. Living life as an experiment means to be consciously aware and actively engaged in one's own becoming, that is, in other words, minding the direction one's life takes and which Ideas one's life is invested in expressing. The question of how one might live seems to inevitably find its consummation in another question: what is it that one might express in one's becoming? This question, however, falls back to prescriptive answers and a 'might' that collapses to a 'should'. It is not that the question cannot or should not be answered, only that possible answers are individuations that receive their ultimate validation only in the immediacy of a singular event of cognition and in relation to a complex arena of interactions. These are never supported by anything given *a priori*.

In the course of such individuations, one is up to negotiate a more profound challenge: the intensive interplay between freedom and significance. The determinable but not yet determined presents freedom in its most distilled form. It is not anyone's freedom yet it is inherent to every individual[3]. This freedom, however, is meaningless without individuated expression. Every determination, the very movement of thought from virtual difference to actual expression, is a transformation of freedom into significance. In meaningful expression, significance is gained at the cost of one's freedom via choices being made, symmetries being broken and directions committed to. The momentary total expression is a manifestation of one's freedom but is itself, in the moment of actualization, a determination that will irreversibly affect consequent paths of individuation. Thus it is present as a necessity and constraint.

[3]Asserting freedom as 'my freedom', trying to own it, is an act of transforming freedom to significance.

But there are in the course of individuation parallel processes of counter actualization. Determinations are reversed, singularities and distinctions fade and disappear, boundaries are dissolved, structure and pattern disintegrate and broken symmetries are reinstated. Freedom is gained at the cost of significance. Yet no one stands in loss because the individual determined by that significance is no more. Paths of selection that were not available open, but the one who could reflect on them as concrete possibilities, as excess of freedom owned, no longer exists. Becoming free eliminates the possibility of such reflection. Freedom and significance are disparate but strangely are also standing in relations of internality.

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This is a beginning of a new style of thinking and a new style of being in becoming – "Through it cognition has been produced in me…"[4]

[4]See quote at the beginning p. 1.

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