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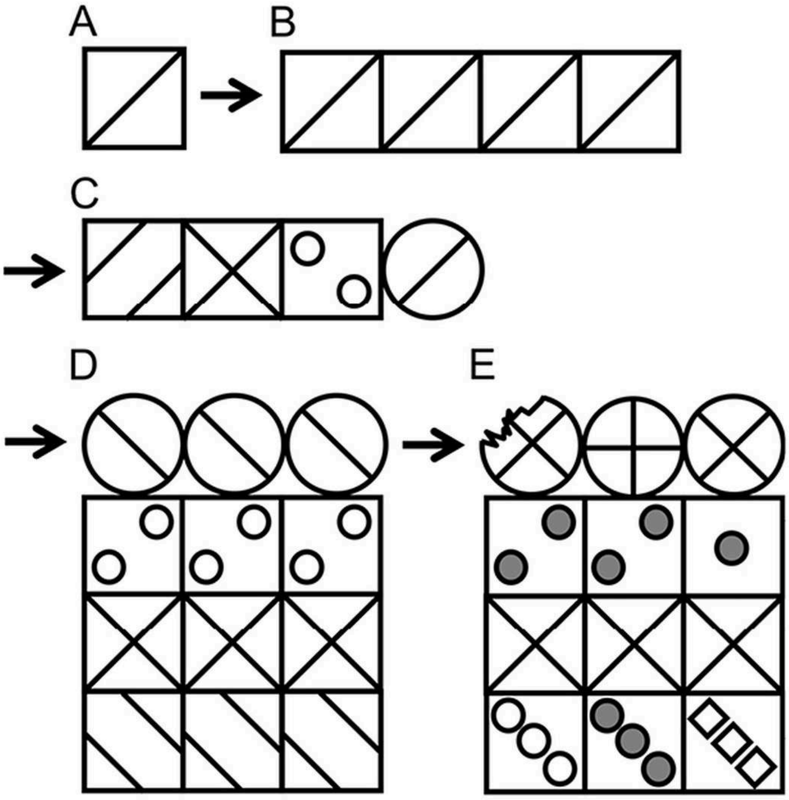

GEORGES CHAPOUTHIER

THE MOSAIC THEORY OF NATURAL COMPLEXITY

A SCIENTIFIC AND PHILOSOPHICAL APPROACH

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The Mosaic Theory of Natural Complexity

A scientific and philosophical approach

Georges Chapouthier

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What is complexity? The present work will offer a description of complex systems based on two general principles: **juxtaposition** of similar units and then **integration** of these units, once modified, into structures at a higher level of which they become parts. As in a **mosaic**, however, these parts within the higher level or structure, retain some independent properties and autonomy. The model is based directly on observations of living organisms: cells or organs retain their autonomy functioning within a given organism, and individual organisms have autonomy when functioning as part of a population or society.

Qu'est-ce que la complexité ? Le présent travail offre une description des systèmes complexes basés sur deux principes généraux : la juxtaposition d'unités similaires et l'intégration de ces unités, une fois modifiées, dans des structures de niveau supérieur dont ils deviennent parties. Comme dans une mosaïque, cependant, ces parties conservent certaines propriétés indépendantes et de l'autonomie. Le modèle est basé directement sur les observations des organismes vivants : des cellules ou des organes conservent leur autonomie de fonctionnement au sein d'un organisme donné, et les organismes individuels ont une autonomie lorsqu'ils fonctionnent dans le cadre d'une population ou d'une société.

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Preface

Peter McCormick

1 Readers of The Mosaic Theory of Natural Complexity, the internationally distinguished French neuroscientist and philosopher Georges Chapouthier's outstanding recent work, will most likely want to reflect critically on several central issues in science and philosophy today[1]. For his well-considered title raises at least three important, and persistent, questions: What is a theory?, What is a theory of natural complexity?, and, specifically, What is Chapouthier's mosaic theory of natural complexity?

2 Assembling here some linguistic reminders proves useful. Take the still vexed issue of theory. Scientists and philosophers continue to disagree about just what the overly familiar English language word "theory" denotes. No wonder. For in everyday British English, the expression "theory" standardly[2] denotes any one or more of four progressively more abstract matters.

3 Thus, according to the examples in the latest edition of the two volumes Shorter Oxford English Dictionary[3], the word "theory" may denote a speculative (esp. fanciful) view or an "unsubstantiated hypothesis", as in the citation from E. M. Forster, "He had a theory that musicians are incredibly complex." "Theory" may also denote a "statement of rules or principles of doing something," as Day Lewis's observation, "My aunts and uncles had… no theories about child upbringing." Again, "theory" may denote "the exposition of the general principles of an art or science…," as in R. Warner's recollection, "We studied the whole theory of flight." Or finally "theory" may also denote "the systematic conception of something… established by observation or experiment esp. as distinguished from the practice of it," as in A. Koestler's allusion to "Contradictory theories about the forces which make planets revolve."

4 Now when, unlike lexicologists, scientists talk of "theory," they often focus sharply on the last of these everyday uses. Accordingly, they usually understand the expression "theory" mainly with respect to "law" and "hypothesis." Thus scientists take a scientific law standardly as any "descriptive principle of nature that holds in all circumstances covered by the wording of the law," whereas they call any such descriptive principle that "has not achieved the incontrovertible status of a law" a

theory. By contrast, a hypothesis is either a law or a theory that “retains the suggestion that it may not be universally applicable[4].”

5 In turn, philosophers generally narrow the scope of the expression “theory” even more so[5]. In the positivistic era of the philosophy of science for instance, acceptable scientific theories were considered largely according to the strict terms of those that fully satisfied all the demands of axiomatic systems. Satisfactory scientific theories were those where empirical observations served as foundations for all theoretical terms. Much later, however, many working scientists adopted a looser understanding of theory. Similarly, many philosophers of science also began to think of theory in less formal ways. These more recent approaches included historically inspired ideas about theories, not as always necessarily closed axiomatic systems, but as, sometimes, open-ended heuristic models.

6 The point then of these representative linguistic reminders is that special care must be taken when talking in both scientific and philosophical contexts today of “theory.”

7 What then are we to make of Georges Chapouthier’s concerns not just with theory but with what he calls a “theory of naturalistic complexity?” What kind of a theory is that?

8 In his professional contexts of contemporary science and philosophy, the complexity Chapouthier mainly has in mind does not centrally concern the physical complexity of certain physical systems. In such systems complexity is the characteristic that enables them to accommodate different physical states by allowing for phase transitions from one state to another. Examples are the phenomena of change from the solid to the liquid state, or change from the liquid to the gaseous. Nor is it the physical complexity of certain physical systems that enables them to exhibit over long range spatial coherence, as in the phenomena of superconductivity and the emission of laser radiation. Rather, the complexity at issue here is naturalistic in the particular senses of being on exhibit especially in theoretical biological contexts and not in theoretical physical ones.

9 Thus, complexity here means generally the levels of self-organization not of a physical system but of a biological one. And the self-organization at issue is the spontaneous order arising not in any physical or chemical system, but particularly in a biological system open to its environment[6].

10 Now the idea of naturalistic biological complexity draws attention to the different rates in which some different parts of a biological organism may evolve with respect to its other parts, whether relatively slowly or relatively quickly. What permits great flexibility in the observable characteristics of an organism, its phenotype, is its genes, “the dominance relations among their alleles,” and their evolutionary interactions with their environments. Standardly, then, “when a population is faced with new selection procedures in a changing environment, only the most crucial components need evolve, not the entire phenotype.” This phenomenon is called “mosaic evolution[7].”

11 But what then, specifically, is Chapouthier’s “mosaic theory of naturalistic complexity?

12 This book of course gives his answer. But perhaps we may say here, however briefly, that Chapouthier’s mosaic theory of naturalistic complexity is “a description of complex systems, from living beings to mind processes, based on two general principles: juxtaposition of similar units and then integration of these units, once modified, into structures at a higher level of which they become parts. As in a mosaic,

these parts within the higher level structure retain some independent properties and autonomy."

13 Finding a truly authoritative and commendably concise scientific and philosophical discussion of a mosaic theory of natural complexity that forces second thoughts about such salient issues today as the nature of scientific theories and the shifting ideas of naturalistic complexity is exceedingly difficult. Thanks to his truly excellent essay, Georges Chapouthier has not only crystallized his distinguished work of many years; he has put a number of reflective persons today deeply in his debt.

NOTES

1. For a brief sketch of Georges Chapouthier's professional career and many publications see David Viterbo, « *Françoise Tristani-Potteaux et Georges Chapouthier, Le chercheur et la souris* », *Histoire de la recherche contemporaine*, Tome III, N°2 (Paris : CNRS, 2014), 190-192 ; also available [on line: http://hrc.revues.org/878].

2. Although understanding such cardinal terms usually requires rather lengthy argumentative treatment, here I understand these terms in the standard senses on record in current professional reference works.

3. *SOED,* 6th ed. (Oxford: OUP, 2007). By comparison, note that for American English *The American Heritage Dictionary of the English Language* (4^{th} ed., Boston: Houghton Miflin, 2000) provides six basic senses of the polyvalent word, "theory."

4. See "Laws, Theories, and Hypotheses," in *A Dictionary of Science,* 6^{th} ed. John Daintith and Elizabeth Martin (Oxford: OUP, 2010), p. 466.

5. Cf. Simon Blackburn, *The Oxford Dictionary of Philosophy,* 2^{nd} ed. (Oxford: OUP, 2005), p. 363-364.

6. Note however the related but contrasting discussion of "self-organization" in computer theory in Arthur W. Burks, "Computer Theory," in *The Cambridge Dictionary of Philosophy,* ed. Robert Audi, 3^{rd} ed. (Cambridge: CUP, 2015), p. 189-192, esp. p. 191 on "human-computer combines."

7. See "Mosaic Evolution" in the *Oxford Dictionary of Science*; cf. the entries there on "Complexity" and "Self-Organization" which I have also relied on here. For the larger contexts see, among others, Peter Godfrey-Smith, *The Philosophy of Biology* (Princeton: Princeton UP, 2014), esp. p. 68-75.

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Summary

1 What is complexity? The present work will offer a description of complex systems based on two general principles: **juxtaposition** of similar units and then **integration** of these units, once modified, into structures at a higher level of which they become parts. As in a **mosaic**, however, these parts within the higher level or structure, retain some independent properties and autonomy. The model is based directly on observations of living organisms: cells or organs retain their autonomy functioning within a given organism, and individual organisms have autonomy when functioning as part of a population or society; or areas of the brain have autonomy when operating as part of the overall functioning of the whole brain. The model is compatible with Darwinian approaches and can offer an epistemological rehabilitation of the role of asexual reproduction which has only too often been overlooked. The argument is that the anatomical complexity of living beings mainly arises from the non-separation of structures such as cells or "twins" produced through asexual reproduction and subsequent integration.

2 The mosaic model can also be broadly used to describe memory, consciousness, language, drawing, music, technical objects, urban planning, mathematics and information theory, social structures, dialectics, ethical stances and literary approaches. Arguments for the mosaic model can also be found in various elements in cultures and animal (proto) cultures (*e.g.* the use of tools, cognitive rules, communication and language, or evidence of practicing moral behaviour or aesthetic choices).

3 In philosophical terms, the model can be related to the Biocosmological or neo-Aristotelian stance as argued by the Russian philosopher Konstantin Khroutski. The concept of triunity developed by Khroutski may be applied to the general philosophical concept of dialectics, both at the materialistic level (in line with Engels' Dialectics of Nature) and at the ideological level (in line with Hegelian dialectic). The mosaic model can fit von Bertalanffy's holistic General System Theory that similar principles can be found in different theoretical or scientific fields. The involvement of mosaic structures could be put forth as one such general principle.

4 The mosaic model of complexity has strong links with three philosophical approaches: the neo-Aristotelian approach, the ubiquitous concept of dialectics and the General

System Theory. It can also offer an understanding of why knowledge is possible: the brain being built according to the same principles as the rest of the world (principles including complexity in mosaic formations), it can mimic and simulate the rest of the world and lead to scientific knowledge.

Introduction

1 What is complexity?

2 On the planet Earth it is usually assumed that living organisms, built on the complex architecture of carbon-based molecules, are the most complex systems that we can directly observe. The human brain, displaying evidence that huge quantities of memorized information are processed, is possibly the most complex structure on earth.

3 Despite attempts by mathematicians, it is not possible to give a clear-cut definition of what complexity is. The model presented here is not aimed at approaching complexity through mathematical considerations, but focuses on straightforward observations of living beings and the way they are built. It is one of a number of possible models of complexity. It is intended to describe structure of complexity as it appears in living beings, showing how complexity emerges in the world we live in.

4 As will be shown later, this model (named “Complexity in Mosaics”) comes from two main principles: “Juxtaposition” of similar structures and the subsequent “Integration” of these structures to produce structures at a higher level, a process that can be repeated several times in biological systems, leading to the well-known architecture of life, offering a series of levels ranging from cellular to populations and species.

5 There is no need for a sophisticated definition of complexity; a level such as an organism, built on structures at lower levels, *e.g.* cells or organs, will be considered as more complex that its lower levels components. Similarly, an organ will be considered as more complex that its component cells, a population more complex than its components individual organisms, and so on. This practical point of view avoids the need for an (impossible?) definition of complexity.

6 The mosaic model can be used for accurate description of the complexity of living beings, with its scope including not only individual organisms and populations, but also genes, organs and groups of organs, as many examples will show. This leads to a specific role for the model in relation to Darwinism, as will be discussed. The model can be applied to properties that are linked to but different from biological systems. Mind processes such as memory, consciousness and language can be analyzed in terms of mosaics, as well as can other phenomena produced by the mind: literature, art and philosophy. The mosaic model thus offers a broad range of possible uses across

numerous psychological and literary fields. The model will therefore be useful in both biology and social sciences.

7 In Aristotelian philosophy, a modern stance was introduced by the Russian medical doctor and philosopher Konstantin Khroutski with “Biocosmology” also known as “Neo-Aristotelism[8]”, focusing on Aristotle’s argument that the universe is built biologically, not physically. In modern terms, this does not mean that the universe is simply a huge ape like King Kong, but rather that the very structure of complexity everywhere in the universe may have biological elements. Knowledge of rules governing complexity in living beings might therefore be an approach to a general understanding of complexity processes. I have adopted this point of view and one section of the present text will be devoted to the possible extension of the mosaic model beyond the realm of living beings on earth, exploring derivates for the models, *e.g.* in mind processes. The possibility of applying this originally biological theory outside the field of biology will be covered. At the same time it will be apparent that my thesis on complexity as a mosaic formation is compatible with another thesis put forth by Konstantin Khroutski’s Biocosmological school, and that is the thesis of triunity in biological phenomena: this will then be related to the dialectics of life.

8 Another important point that will be discussed is the relationship between nature and culture. Though human culture may sometimes be in opposition to nature, the origins of culture show that culture is an extension of what nature had already started. This can explain why principles governing nature and principles governing culture, *i.e.* complexity in mosaics and/or the triune dialectical movement, are likely to be the same, supporting the Biocosmological stance that the laws of the universe are indeed universal.

9 As the present work on complexity as a mosaic phenomenon is at the intersection between biological theory and philosophical speculation, it involves both hard science (*e.g.* biology and astrophysics) and human and social sciences. It thus attempts to provide new and general answers to the scientific and metaphysical question of natural complexity.

10 Some of my arguments have been published (in French and English) as articles and books[9], but this is the first time I have had the opportunity to present an extended albeit succinct view covering the scope of the theory.

NOTES

8. Khroutski 2008, 2013.

9. Chapouthier 2001, 2009a, 2011; Audouze *et al.*, 2015a.

Chapter 1. Mosaic Architecture in Living Beings

The evolutionary path towards complexity

1 Why has evolution given rise to a certain number of living beings of great complexity? This is obviously not the case for all species and organisms, as some have evolved *down* the "complexity hierarchy[10]". Evolutionary processes can lead to an *increase* as well as a *decrease* in the anatomical complexity of organisms. Extreme cases of such a decrease can be seen with certain parasites, *e.g.* the tape worm (*taenia*) with an anatomical structure inferior to the structure of what was probably the free-moving evolutionary predecessor. In general, however, observations show that more complex beings exist now than in earlier times. The general trend of evolutionary processes seems to be towards *increased* complexity. The arguments developed in the present text will be that this trend cannot have been caused solely by random processes, that some powerful organizing mechanisms have been involved in the development towards complexity.

2 In relation to Darwinian processes, the hypothesis presented here is compatible with Darwin's theory of evolution and evolutionary reasoning, and specifically with processes of natural selection as argued by Darwin. While I am clearly a Darwinian, I do not believe that Darwin's natural selection theory can explain everything in evolutionary processes. I believe that in the field a complexity there is space for general integrating mechanisms as a complement to natural selection. The mosaic theory I am advocating here clearly concerns such general integrating mechanisms.

Juxtaposition, integration and mosaic structures

3 I shall first present the integrating mechanisms which, I believe, are involved in biological evolution towards complexity and shall then provide several concrete examples of their appearance in biological systems.

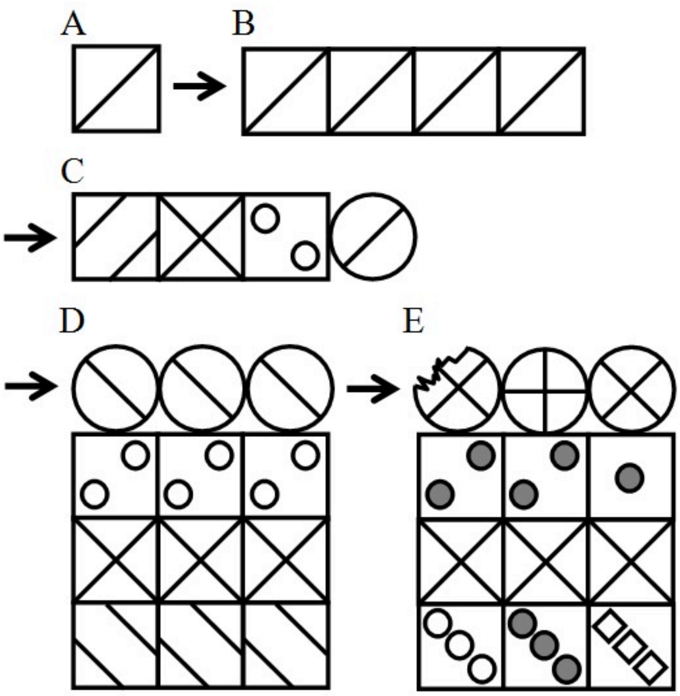
4 The principles underlying my argument are two basic operations, which I have named Juxtaposition and Integration[11]". Juxtaposition, as the term suggests, is the

accumulative positioning of identical or similar units, one next to the other, a process similar to forming a necklace with identical or similar beads. Cells grouped to form an organ, or birds gathering together at night to sleep can be cited as examples of the juxtaposition process. In a juxtaposed arrangement, all juxtaposed units have more or less the same function; there is no hierarchy; none is under the command of another.

5 Integration involves a process which differentiates and combines the original units, thus generating entities one step up the hierarchy, comprised of the same original units which then become component parts, *e.g.* a necklace with beads of different colours or shapes forming a snake-like image. Organs developing for the harmonious functioning of an organism, or bees together in the complex structure of a hive, can also be cited as simple examples of the integration process.

6 By further juxtaposition and subsequent integration, new higher level structures (*e.g.* necklaces of necklaces, or necklaces of necklaces of necklaces) can then produced. Figure 1 is a diagram illustrating the processes.

Figure 1 - Juxtaposition and integration.



Single identical units (A) can be added (juxtaposition, B). Changes can then occur in B juxtaposed structures to produce C (integration). By further juxtaposition (D) and subsequent integration (E), new higher level structures can be produced. In theory these processes can be repeated ad infinitum to produce ever higher levels of complexity. In practice, at least in biology, there are limits, *e.g.* combinations of colonies of organisms. Adapted from G. Chapouthier, L'Homme, ce singe en mosaïque, Odile Jacob Publisher, Paris, 2001.

7 A convenient model for these juxtaposition and integration processes is the art of the mosaic: small ceramic tiles – *tesserae* – are juxtaposed and integrated in a mosaic to depict a figure, yet each individual tile retains its own distinctive features (shape, size, texture and colour). In philosophical terms, the properties of the complete mosaic subsume the component parts but do not cancel out the autonomous existence of the

properties of these component parts. In this metaphor of mosaics, as in the art of mosaics, the whole, *i.e.* a set level of a living being, still leaves its component parts with autonomous properties. The mosaic is thus used as a general model expressing the different levels of complexity of living beings. Venturing beyond the realm of living organisms, as will be seen later, the mosaic metaphor can be used to describe a number of structures with organization similar to that of living organisms with integration occurring at one level yet leaving lower level units in a state of relative autonomy.

8 Let us first look at examples of living organisms with many cases of mosaic architecture arising from repeated juxtaposition and integration.

Genetics

9 In the field of genetics, the genome can be subdivided into exons which are the gene segments responsible for (*i.e.* coding for) chemical actions in the cell and ultimately the way it lives (it metabolism), and introns which are silent genes with no direct active function. With time, introns can duplicate, and the silent duplication of introns may be seen as a form of *juxtaposition* of identical elements. It has been argued that juxtaposed introns may then silently undergo multiple mutations over time, developing patterns (*i.e. integration* of component parts) that can ultimately be expressed as functional exons and code for new organs and/or functions. This has been reported by authors such as Ohno[12], arguing that it is one of the basic processes of genetic evolution. This genetic hypothesis may offer an explanation of the development of new complex organs, for when the complex set of integrated introns emerges as exons, their action (on a new function or organ) could then be selected through natural selection. When a new set of exons is useful to the animal, it will be selected and survive; in the opposite case, it will disappear. This selective process thus fits traditional Darwinian theory. The processes of duplication of introns and mutations to create new genetic structures which can later emerge as exons may be considered, before natural selection, as mosaics processes as defined in the present text.

Molecular level

10 At the molecular level, several biologically active macromolecules (hormones, enzymes, receptors, toxins etc.) can be given as examples of juxtaposed and integrated structures. I have chosen two of the many possible examples: the botulinum toxin and the GABA A receptor complex.

11 The botulinum toxin is a powerful neurotoxic substance secreted by the bacterium *Clostridium botulinum* and related bacteria. Its main action is to block the release of acetylcholine, one of the most useful brain neurotransmitters. Botulinum toxin is a macromolecular complex of several (juxtaposed) units with a neuroactive (toxic) component and several associated non-toxic proteins. Thus the botulinum toxin can be seen as a molecular juxtaposition of units where the functional action emerges from efficient integration of the different parts[13].

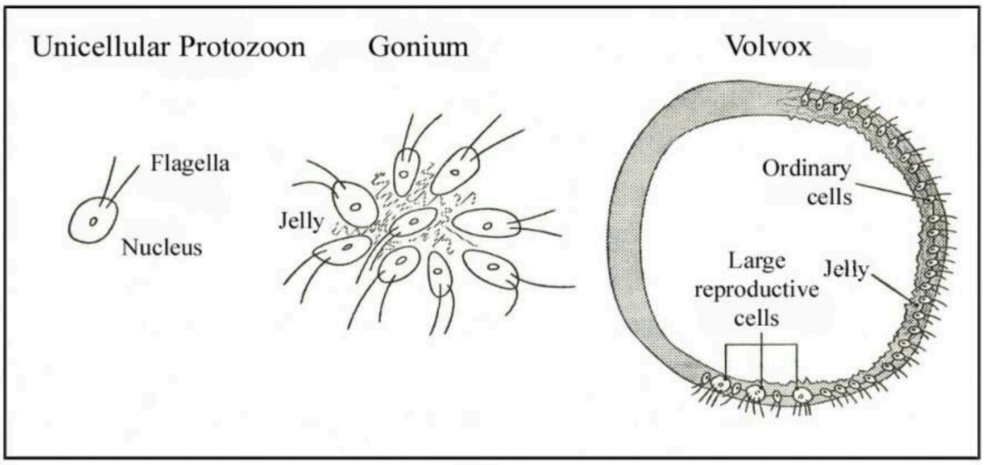
12 In contrast, GABA (gamma-Aminobutyric acid) is the most important inhibitory neurotransmitter in the central nervous system, being present in nearly one-third of the brain synapses. The GABA A receptor complex is a group of five juxtaposed subunits

located on the membrane of the nerve cell. When activated by GABA, the receptor complex acts on the chloride channel making it possible for chloride to enter the nerve cells, causing hyperpolarization of the membrane and blocking nerve impulses. GABA can have antiepileptic effects, can counter anxiety (anxiolytic actions) and can have a negative impact on memory (amnestic actions[14]). Independently of the reception and actions of the GABA molecule (the main ligand on the receptor complex), GABA subunits are also specific for the reception and correlated actions of other ligands, as can be seen with pharmaceutically active compounds such as antiepileptic drugs, barbiturates, anaesthetics, benzodiazepines and alcohol. Here too, the functional action of the receptor complex is the result of the integration of the five juxtaposed subunits activated by their different ligands[15].

Anatomy

13 Looking at the anatomy of organisms, in unicellular organisms, two principles can be seen at work when isolated cells evolve to become either a juxtaposed organism, *e.g.* Gonium (with all juxtaposed cells playing exactly the same role), or an integrated organism, *e.g.* Volvox, (with different types of cells living together, suggesting that an integrating process is beginning and will develop into multicellular organisms, see figure 2). In multicellular animals, two types of anatomical organization operate, either as two layers of cells, one external and one internal (*i.e.* "didermal" animals such as polyps), or three layers of cells with bone and/or muscle forming an intermediate layer ("tridermal" animals, ranging from worms to insects vertebrates).

Figure 2 – Emergence of complexity in unicellular organisms.

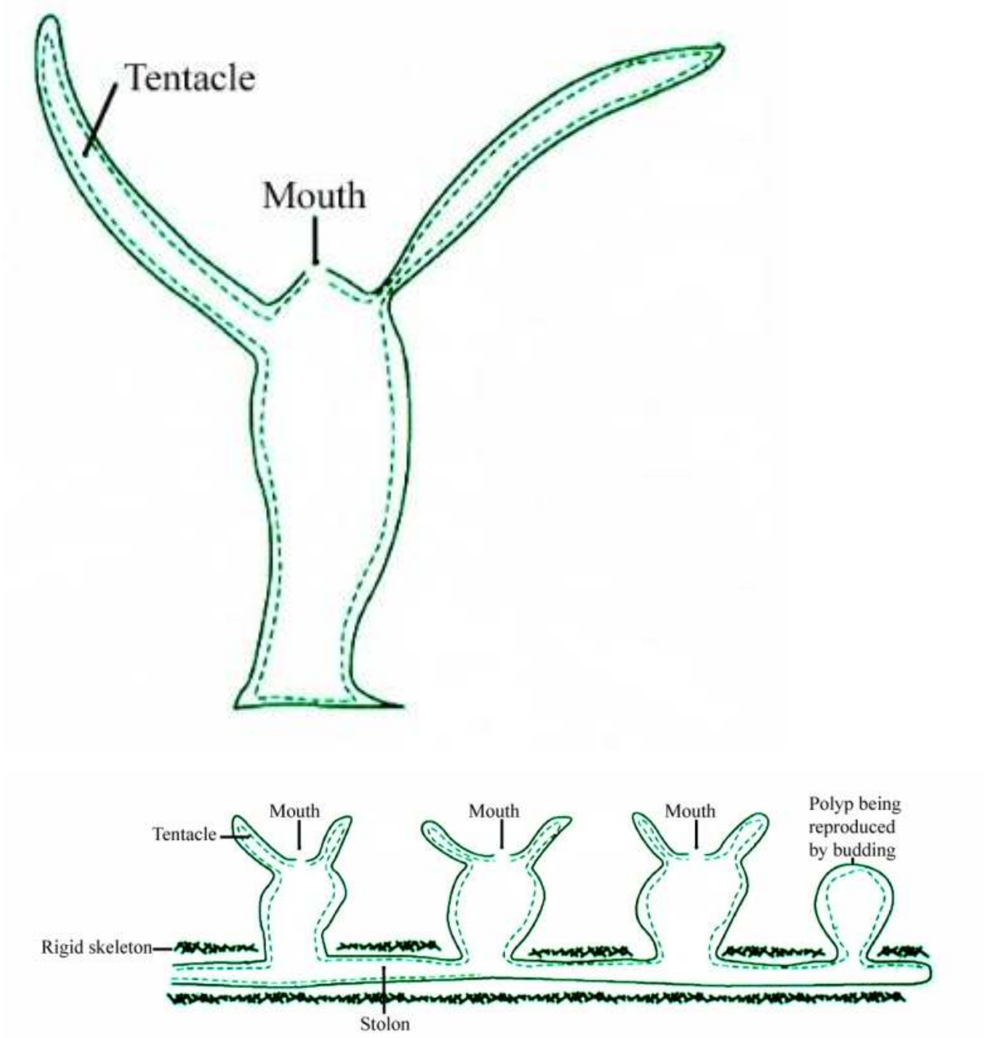


In unicellular organisms, juxtaposition can produce structures such as Gonium, and integration can produce structures such as Volvox, these being on a higher level in evolutionary processes. Reproduced, with permission from the publisher, from G. Chapouthier, L'Homme, ce singe en mosaïque, Odile Jacob Publisher, Paris, 2001.

14 In addition to individual isolated polyps such as sea anemones or jellyfish, two-layer species can produce huge collections of identical polyps juxtaposed over kilometres, as in vast coral reefs (see figure 3). But there are also colonies of non-identical elements such as siphonophorae floating on the sea, comprised of different types of polyps

(defensive, floating, digestive and reproductive) forming a group as a mosaic colony. In a siphonophora, each polyp is one part of the extensively integrated colony.

Figure 3 – Emergence of complexity in two-layer organisms.



In two-layer species, single polyps (top) are juxtaposed to produce colonies of identical polyps (bottom). Integration (not shown) produces colonies of siphonophorae, with different types of polyps (defensive, floating, digestive and reproductive). With permission from the publisher, from G. Chapouthier, L'Homme, ce singe en mosaïque, published by Odile Jacob, Paris, 2001.

15 In three-layer organisms, animals such as the earthworm are formed of largely juxtaposed segments called metameres. Equivalents of individual (single) metameres can also be found free, *e.g.* in certain worms such as planarians. While earthworms can be seen as a mainly juxtaposed structure, metameres are also observed, to varying degrees, in more integrated animals. Most animals, whether insects, molluscs or vertebrates, are integrated structures with an earthworm-like arrangement but with different locations for the nervous system (dorsal in vertebrates and ventral in molluscs and insects), but this cannot be analyzed here. It not easy to identify the original metameres in these developed animals, although there are some exceptions: the segmented insect abdomen or the segmented ribs and vertebrae of vertebrates, clearly revealing the original juxtaposition in these mainly integrated organisms. Expressed differently, the segments of the bee abdomen and the segmentation of

chimpanzee ribs and vertebrae are remnants of prior construction by juxtaposition still visible in the integrated organism.

16 Can the principle of juxtaposition apply to complete organisms such as the bee, chimpanzee or human being? The human being can provide the case of anatomical juxtaposition of two individuals with Siamese twins. However, as humans are constantly moving, any bid to extend this juxtaposed situation into something which could be considered proper integration is greatly limited. Partially integrated Siamese twins as observed and reported (with striking cases of sisters with two heads but only one abdomen, or only two legs for two twins) are exceptional cases and therefore not likely to be included in Darwinian selection.

17 At the level of organisms, juxtaposition is more likely to be social that anatomical.

Social structures in animals

18 Social contact provides a context for complex three-layer organisms, such (*e.g.* bees or primates) to be governed by the principles of juxtaposition and integration, ultimately producing social mosaics. Some animals adopt juxtaposed settings, *e.g.* birds gathering together to sleep or forming flocks when all have the same role or are part of the same purpose. In sophisticated cases such as the bee hive or troops of primates, the situation is clearly integration with different subjects having different roles and serving different purposes: the queen bee, worker or male in the hive (and similar examples could be given with termites and other ants), the mothers, young females, dominant males and peripheral males in primate troops. And it is obvious that in societies of human primates all individuals have different social roles. With individuals as parts, animal societies can be seen as integrated mosaics.

19 In human societies, integration can be developed to varying degrees. The degree of autonomy of individual subjects (the parts) in relation to society (the whole) is the measure of what can be called freedom. In democratic societies, there is obviously greater – freedom – for individuals than there is in totalitarian societies. The case of human societies will be developed later when analyzing the mosaic architecture of the human mind and its capabilities.

20 All integrated levels of living beings, whether cells, polyps, metameres or individuals, still have basic units at a lower level retaining a certain degree of autonomy, even though they are now part of a whole at a higher level. This is the mosaic model, similar to the combination of individual tiles (tesserae) in an artistic mosaic. In biology, the properties at a given level form a whole, while still leaving a relative degree of autonomy to the component parts. Examples can be found with the organization of physical organs, but I shall focus on the brain, the essential organ for the mind, devoting the next chapter to the human brain.

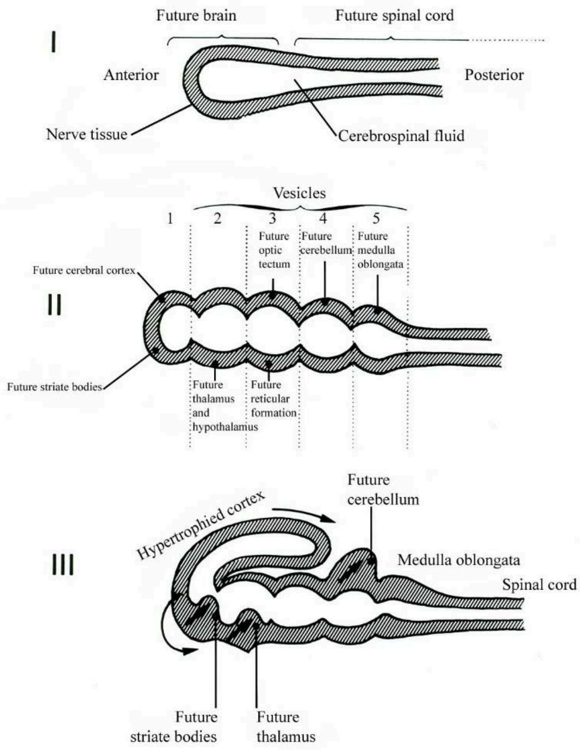
The Human Brain

21 The human brain is the most complex structure known to science, and mosaic-like features and processes can be identified in it.

22 The brain initially forms as five encephalic vesicles, juxtaposed at the embryonic stage and later integrated until reaching the complex stage of the adult brain (see figure 4).

The brain is clearly the result of a succession of juxtaposition processes and integration processes.

Figure 4 – Emergence of complexity in the brain.



The brain in the embryonic stage starts as a single vesicle (top), then becomes a juxtaposition of five encephalic vesicles (middle) which are subsequently integrated in the course of a preliminary stage before ultimately becoming the structure of the adult brain (bottom). Reproduced with permission from the publisher, G. Chapouthier, L'Homme, ce singe en mosaïque, published by Odile Jacob, Paris, 2001.

23 We shall examine the higher part of the brain, the roof of the first vesicle and known as the cerebral cortex; in the human brain it is mainly what is comprised of the neocortex. The neocortex of the human brain is so extensive that it covers much of the other structures and divides itself into two hemispheres, left and right. The cerebral neocortex can be seen as a mosaic of a number of functional areas (for the senses and motor skills) which control the expression and understanding of spoken and written language, sight and hearing, and areas for "higher" functions such as attention. Each area has specific functions, but they still contribute harmoniously to the workings of the cerebral cortex (the whole). The cerebral cortex offers a fine example of an organ operating as a mosaic of different stage, initially juxtaposed during the embryonic and throughout development until full integration as an adult.

24 The two hemispheres of the brain deserve attention. In primitive vertebrates they are simply juxtaposed, each one controlling the contralateral side of the body. Observations of certain birds and mammals show that the two hemispheres have achieved a level of integration, each acquiring specific functions not performed by the other hemisphere; *e.g.* bird song is often controlled by the left hemisphere. In adult humans, the two hemispheres have very different functions. In right-handed human subjects, the left hemisphere manages analytical processes such as language, and the

right hemisphere covers more general processes such as the perception of images. In normal subjects, the two hemispheres operate in harmony as a two-part mosaic. In pathological cases, however, "split-brain" subjects have suffered an accident breaking the connecting fibres needed for the two hemispheres to communicate (via the brain structure known as the *corpus callosum*); the two hemispheres then are no longer integrated but simply juxtaposed, and the person's brain operates in two parallel and independent ways (the effects on their ability to think will be reported below).

Other biological arguments

25 A number of biological arguments can be presented as evidence to back my mosaic thesis. Some have been developed by other thinkers independently of my own research and can fit my model perfectly, and other authors have made explicit reference to my thesis.

26 Richard E. Michod, a biologist and professor at the Department of Ecology and Evolutionary Biology at the University of Arizona (USA), has developed theses on the complexity of living beings, independently of my philosophical work on mosaic structures, and has reached similar conclusions. Michod has noted how much biological evolution is linked to integration (a term he uses) of (simple) individuals into individuals at a higher level of complexity. He argues that the main reasons that have led to the diversification of living beings and their hierarchical organization are "mutations of individuality", moving from genes to animal societies, going through all the levels of complexity observed in biology, including cells, groups of cells, organs, organisms and societies. Michod's main interest is anatomical complexity; he has not focused, as I have (see below), on thought and language. One of his great achievements is to have experimentally analyzed some of the processes involved. While my position remains speculative, Michod has conducted experiments to uncover the underlying molecular processes behind the switches to different levels of complexity[16] and in particular for the aggregation of cells in the algae Volvox mentioned above in figure 2. The work of Richard E. Michod offers an extremely interesting approach in modern biology investigating what is one of the most puzzling questions of biological evolution – complexity.

27 The important question remaining is how does the switch between juxtaposition and integration occur. On the cellular level, interesting ideas have been developed by Paul B. Rainey and his colleagues on the evolutionary origins of multicellularity[17]. The authors define three possible routes for the transition from multicellular systems comprised of similar cells (MLS1) providing a juxtaposed state to an integrated state (MLS2) where a new multicellular Darwinian being exists independently and is able to have an independent reproductive process. On the first route, single cells can form aggregates which, once established, live their own lives and are able to multiply without requiring the single cell state. In this first case, single cells continue to reproduce as single cells on one level and aggregates reproduce as aggregates on another level. The second route has constant and repeated formation of aggregates from single cells, *i.e.* the aggregates cannot reproduce independently but emerge regularly from single cells. One example is metazoan reproduction with the germ/soma distinction. In the third route, aggregates can be produced repeatedly and regularly by single cells, as is the case for the second route, but these aggregates can also generate

single cells, meaning that a living being can exist in two different states or phases, as single cells or as aggregates that can merge into the other.

28 This view of three possible routes for multicellularity to evolve from unicellular precursors can lead to further analyses of possible underlying genetic mechanisms or further Darwinian or non-Darwinian evolution of these different routes. While an abrupt switch from a unicellular to a multicellular life form may be possible, as in route 1 with aggregates immediately separating from their single cell precursors, the authors argue for a more gradual form of evolution. Routes 2 and 3 would make it possible to have greater "fluidity between individual and group states" and therefore "repeated opportunities to transition[18]". They also note that different pathways followed by the different organisms are "likely to be dependent on specific ecological conditions[19]". And transitions between the three different routes may even be possible before the organism settles into a stable configuration.

29 Further research by the same team[20] included an experimental investigation of the first stages of multicellularity, studying the bacterium Pseudomonas fluorescens which occasionally develops simple multicellular structures. A mutation causes single cells to overproduce cell-cell glue, leading to juxtaposed cell-mats that spread "because the group of mat-forming cells reaps an advantage (access to oxygen) that is denied to individual cells[21]". But the life of these multicellular mats is very brief as "cheating cells" soon appear, these being cells that "do not contribute towards group integrity, but nonetheless take advantage of the benefit that accrues from being part of a collective[22]". "Cheater suppression" may be an important mechanism at the cellular level in the transition towards permanent multicellularity. The experiment subjected a bacterium a "cheat-purging regime" which extended the duration of the multicellular mats. This is the first experimental evidence of the persistence of simple (juxtaposed) multicellular structures.

30 The American scientist Stephen M. Modell[23] began by investigating healthcare, suggesting that general Biocosmological principles could be applied to healthcare which was seen as a general and complex structure; he then extended the scope of his study to the entire living kingdom. Not only is there classical Darwinian selection at the genetic level, but Modell[24] also sees space for "additional laws" to explain the complexity of biological forms, arguing that in evolution "surely there must be more than simple randomness at work." On energy, Modell talks of the involvement of "islands of energetic stability, which, supplemented by selective adaptation, could account for new levels of evolutionary complexity", a position very similar to modern biophysical theories developed by Prigogine[25] and Tonnelat[26]. All of this could ultimately lead to morphological changes in organisms. Modell quotes my hypothesis of duplication (juxtaposition) followed by integration leading to mosaic structures, recognizing that such "combined processes may be responsible for the emergence of complexity" in the human brain, and also seeing it as a possibility at the different morphological levels of living beings. Modell suggests that as a paradigm, these juxtaposition–integration processes demonstrate the thesis-antithesis-synthesis triune common to philosophy and Biocosmology, again focusing on the potential for common ground between modern Biocosmological stances and classical dialectics.

31 The engineer and physiotherapist Moshe Feldenkrais (1904–1984) developed his well known therapeutic method[27] based on a technique involving kinaesthetic feelings: a person practicing the method must learn to feel distinct parts of the body (*e.g.* bones)

separately; analysis of the juxtaposed feelings then leads to better integration, *i.e.* functional integration of movements.

32 In different ways, the thinkers cited above offer arguments for the mosaic model of living beings. It may be done directly, as with the experimental work of Michod, or indirectly, as with Modells's reflections, or even through a clinical and practical approach, as for Feldenkrais, but all can be seen as juxtaposition/integration of simple structures to form more complex ones.

An epistemological rehabilitation of sexual reproduction

33 Living beings have one of two modes of reproduction, sexual and asexual.

34 Sexual reproduction, the most recent in evolutionary terms, "blends" genes during the stage when the two gametes (paternal and maternal) form the egg-cell, although there are variations at this the earliest stage of reproduction. Darwinian selection follows with the ability to select the variations which are useful for the survival of the organism. As sexual reproduction produces such variations at an early stage, it is very well suited to selection. In fact, sexual reproduction is the basis for most Darwinian models.

35 Asexual reproduction produces identical copies of one structure, by first doubling to form two similar structures which eventually separate. Examples of the process can be seen with the growth of biological tissue in organs, plant cuttings, animal polyps and even human twins. If an event prevents the two similar structures from splitting, they remain attached and juxtaposed, but may at a later stage experience variations, thus producing differences, the variations occurring at a later stage.

36 Asexual reproduction is ubiquitous in the living world and can produce complexity through the integration of both juxtaposed and non-separated structures as stated above. My thesis of complexity in mosaic formation thus stands as a clear epistemological rehabilitation of the role of asexual reproduction which is only too often overlooked. The argument is that complexity of living beings mainly arises from the non-separation of structures produced through asexual reproduction and from subsequent integration.

37 The model is compatible with Darwinian theory which I recognize as important for the understanding of the biological diversity produced through sexual reproduction, but the mosaic model is not directly based on Darwinian principles. My arguments could be compared to the approach of the Brazilian philosopher Paulo C. Abrantes[28] in dealing with Darwinian and non-Darwinian multi-level selection in evolutionary dynamics. Abrantes analyzes what he calls "transitions in individuality", *i.e.* transitions from a simple individual level to a broader level, integrating single entities as part of a greater entity; *e.g.* switching from an organism to a population. He shows that to reach a higher level, it is necessary to go through lower-level processes of "de-Darwinization," therefore once the lower level has been subsumed as a part, it is no longer governed by the rules of Darwinian selection.

38 In general, when the mosaic model is compared to Darwinian theory, it can provide an explanation for the emergence of more complex biological systems starting from simple original cells. The in-depth analysis of the mosaic model by the Australian

philosopher Arthur Saniotis[29] included the following comments. “The Mosaic model created by Georges Chapouthier [...] not only challenges biological reductionism but also provides an integral approach towards understanding biological processes[30].” In the present text, I have chosen to focus on complexity rather than emergence, while also recognizing that complexity arising with new properties and from originally simpler structures is indeed a phenomenon of emergence. In other words, the mosaic model is an original way to interpret emergence within biological systems.

Partial conclusion

39 My thesis presented here is an endeavour to interpret the architecture of biological systems. The argument, in line with Darwin’s theory of evolution, explores the development of living beings and their shift towards greater complexity. Basic phenomena, whether in genetics, anatomy or social structures of animal populations, provide the key principles in evolution towards complexity: juxtaposition and integration. These processes produce structures that fit the mosaic principles, *i.e.* juxtaposition, accumulating similar units, and integration, developing into a more sophisticated version with the original units then becoming component parts. Observations of structural and functional complexity in living organisms, in both genetic and anatomical structures, tally with the organizational features of mosaic structures. At the biological level, observations can lead to an important epistemological rehabilitation of asexual reproduction, thus providing a possible explanation for the emergence of more complex organisms during the geological periods.

NOTES

10. Gould *2002.*

11. Chapouthier 2001.

12. Ohno 1970.

13. Poulain 2010.

14. Chapouthier 2003; Venault & Chapouthier 2007.

15. Chapouthier 2003; Venault & Chapouthier 2007.

16. Michod 1999, 2009.

17. Libby & Rainey 2013; Hammerschmidt *et al.* 2014.

18. Libby & Rainey 2013.

19. Libby & Rainey 2013.

20. Hammerschmidt *et al.* 2014.

21. Hammerschmidt *et al.* 2014.

22. Hammerschmidt *et al.* 2014.

23. Modell 2006.

24. Modell 2011.

25. Prigogine & Kondepudi 1998.

26. Tonnelat 1995.
27. Beringer 2010; Feldenkrais 1994.
28. Abrantes 2011.
29. Saniotis 2013.
30. Saniotis 2013: 334.

Chapter 2. Mosaics of the Mind and Repercussions

1 Living beings possessing a central nervous system have a mind. The present discussion will not extend to possible relations between the central nervous system and the mind, but no matter philosophical point of view is adopted, whether materialism or spiritualism, the brain is obviously involved in the functioning of the mind. What we can show here is that mind processes too can be described using the mosaic model. Several examples will be cited for mind-related functions and will include sophisticated activities of the human mind such as philosophy or literature, where the mosaic model can also apply.

Memory

2 Memory is not a single entity, but a mosaic of different capabilities acquired by our animal ancestors in the course of the evolution of the species[31]. Such capabilities include simple memory skills (*e.g.* habituation to a repeated stimulus, and, when in situations requiring a choice to be made between two options, the tendency to choose the less familiar one), and imprinting in response to a stimulus experienced during infancy. More sophisticated memory skills include those seen with Pavlovian and Skinnerian conditioning. These capabilities ultimately include higher functions such as spatial memory and declarative memory (remembering rules and past experiences). Experimental data provide evidence that certain animals have only the most rudimentary form of memory, whereas higher animals, including humans, have all forms, clearly juxtaposed but weakly integrated.

3 The mosaic model proves useful when applied to the different types of memory. We shall focus here on what is called "episodic memory", *i.e.* the memory recalling experiences from the person's own life, including vivid recollections, leading to what we subjectively feel the most deeply to be our memories or recollections. A number of authors argue that episodic recollections form groups as packets or modules within a framework providing a weak semantic link, thus making it possible to recall places, people, actions and events, linking them together. Within one specific episode

remembered, significant details can be identified; for example, I can recall details in my grandfather's orchard: the position of different trees, the green patch of sorrel growing in the middle of the strawberries, and the gravel paths. Then, within such specific details, tiny "micro-details" can be recalled, *e.g.* a few plums on the first tree, the oval shape and bitter taste of the sorrel leaves and the crunching of gravel underfoot. The memory construction, with sets end subsets, can clearly be expressed in the mosaic model.

4 Iglóia *et al.*[32], conducting studies in the field of anatomy, reported on spatial episodic memory in rats, describing the juxtaposition of two different processes occurring in both the right and left hippocampi. Activation of the right hippocampus precedes allocentric spatial representation, whereas activation of the left hippocampus precedes sequential egocentric representation. These results show that "rather than providing a single common function, the two *hippocampi* provide complementary representations for navigation, [...] both of which likely contribute to different aspects of episodic memory." Here we find (anatomical) processes juxtaposed and (weakly) integrated. Without embarking on philosophical relationships between the brain and the mind, it is clear that brain processes can be cited as evidence of the juxtaposition of certain mind processes.

Consciousness

5 Specialists of consciousness state that human consciousness, though psychologically perceived as a whole, is actually a mosaic of several different states[33]. In normal subjects, the distorted images of the dream state offer a different pattern of consciousness. Split-brain patients (mentioned above) with separation of the *corpus callosum*, a structure involved in normal communication between the two hemispheres of the brain, can simultaneously have two distinct states of consciousness (two decision-making centres) that sometimes even compete.

Language and Drawing

6 We conducted an extensive study, in collaboration with Stephane Robert[34], comparing the semantic organization of language with the social organization of living beings and found that language too had a mosaic structure. Language linearity means semantic units ("words") are juxtaposed sequentially and chronologically and thus form a sentence integration conveying meaning. The parallel with living organisms is based on the argument that the preliminary stage of both language and a living organism is one where units are simply juxtaposed. This hypothesis was developed by Talmy Givón[35] who made a distinction between grammatical and pre-grammatical communication. The comparison of the workings of living organisms and of language shows some quite striking similarities in the different processes.

7 Jean-Marie Hombert and Gérard Lenclud[36], in their book on how language developed in humans, quoted our work and adopted the idea, noting that "[...] language offers, in both its organization and evolution, features of the structure of a mosaic [but] unlike individual tiles (*tesserae*) that are spatially arranged in a mosaic, these elements are arranged in time because of constraints inherent in the linear form governing both

spoken and written expression." The authors observe that "in other words, the speaker makes a mosaic, doing so through juxtaposition/integration of discreet component parts."

8 Working in a different field, the language specialist William S. Y. Wang (University of Hong Kong & University of California at Berkeley) published an article making explicit use of the mosaic analogy, referring to the "language mosaic and its biological bases[37]". Wang's analysis focused on the developmental structure of language, describing it as a "multi-layered mosaic" of biological and cultural influences which interact in an age-dependent way, not as the semantic structure of adult language as described in the present article, but his point of view is clearly complementary and in line with the argument we presented with Stephane Robert.

9 Similar approaches can be used with drawing, in particular when studying children and the development of the mind[38], as noted by Baldy (personal communication) who observed two basic visual signifiers, the circle and the line. When a circle and a number of lines are juxtaposed in a certain arrangement, signifiers of a higher order of complexity can be produced: *e.g.* a radiating shape. Depending on the context, the shape depicted may be interpreted as the sun or part of the human body, *e.g.* a head with hair, an eye with eyelashes, or a chubby hand with fingers. During childhood, graphic signifiers start off as simple geometric shapes (circles, lines, squares) and tend later to become more specific: an eye drawn as a circle will become almond-shaped and be more like a real eye. Throughout the process, shapes of a higher order of complexity become less polysemous.

Music

10 Marshall Heiser (Queensland Conservatorium of Music, Griffith University, Australia) conducted an in-depth analysis of Brian Wilson's aborted Beach Boys' album *SMiLE*[39]. According to Heiser, "one of the most well documented recording projects in the history of rock music is one that was never actually completed. *SMiLE* was to be the follow-up album to The Beach Boys' first million-selling single *Good Vibrations* (1966)." The project was scrapped after ten months of sessions and approximately fifty hours of tape, but a three-movement symphonic version was eventually released in 2004 as *Brian Wilson presents SMiLE*. Heiser analyzed the tapes and concluded that there was clearly a "mosaic structure" to the work, where "emergent forms display characteristics not inherent within their parts". Heiser referred explicitly to our mosaic model and processes of juxtaposition and integration in describing what he called "Brian Wilson's musical mosaic".

Technical objects

11 As the mosaic model can be used to describe both animal and human minds, it is not surprising that it can also be useful for describing systems based on the functioning of the human mind, *i.e.* technical objects. The robotics specialist Frederic Kaplan[40] stated that "technical evolution also proceeds by juxtaposition and integration". A new set is first created by combining elementary technical objects and this system is poorly integrated. The technical construction then develops as the elements tend to swap and change, creating "a coherent and unified whole" (p. 18). After a certain time for

technical development, an object (*e.g.* a printer, airplane, motor car or computer) is more highly integrated than it was when first designed. A similar analysis was later developed by the robotics specialist Pierre-Yves Oudeyer[41]. Referring to robots, he noted that “at the beginning of the years 2000… a new technical step was reached, allowing a new level in the way machines are organized in systems; this new step is the juxtaposition and integration, at a large scale, of these dynamic behavioural objects.” One example is with populations of robots able to interact and even to develop among them cultural and language conventions between themselves.

Urban planning

12 According to the architect Denis Laming, in a chapter on the town (*La ville*)[42], “Towns [...] are markers of civilization: they are born, they grow, they get more complex and finally die… This ontogenetic evolution, followed by an entropic evolution (see chapter 4, Nature and culture against entropy) follows a process which offers many common points with the universe, with living beings and with artificial intelligence, according to the mosaic model devised by Georges Chapouthier.”

Mathematics and information theory

13 The Serbian philosopher Milan Tasic[43] has suggested that the mosaic model could be used in mathematical studies, but to date, no full-scale mathematical expression of the model has been devised. A more specific mathematical study may be referred to here. Demongeot and his fellow researchers[44], working in the field of neural networks and memory, used a mathematical approach to analyze mnesic evocation through the action of “populations of coupled neuronal oscillators (that) can dynamically store information in the form of a periodic attractor of large dimension[45].” These coupled neuronal oscillators, inducing bio-electric synchronisation/desynchronization phenomena as described by the authors can be seen as a juxtaposition of two parallel structures of the same level of complexity, ultimately leading to mnesic evocation, which can be described as the integration of the basic phenomena. It would be interesting to have further mathematical work investigating the mosaic model.

14 In the field of information theory, Ugolev and Ivashkin[46] proposed a theory of elementary functional blocks where “complex functions could be reached due to the recombination and transposition of a large though limited set of molecular machines realizing elementary biological operations.” The theory of Ugolev and Ivashkin could be interpreted as an extension of the juxtaposition/integration model applied to information processing.

Social structures

15 In the previous chapter, we observed that animal populations followed the same rules of complexity as organisms forming cellular populations. We also reported that human societies provide evidence of the same mosaic architecture. On the question of the development of the human mind in the present chapter, some sociological examples can be cited in support of the analogy between animal and human societies (see

Chapter 1) and as evidence of the human mind being a mosaic formation, even for social activities.

16 In the fields of anthropology and sociology, a number of studies have investigated mosaic features. Guja[47] devised informational anthropology where "a human being as the system/interface may be considered a fundamental component of her/his human society and the nature/cosmos system as well, just like a hydrogen atom is the elementary constituent of matter under the material form." Sorokin[48] called for a "new sociology" able to reconcile mutually exclusive or contradictory theories. Sorokin's argument is that "sound parts can be unified and incorporated into a more multidimensional and more adequate integral theory... (an) integral sociology to come" presenting another view with a relationship that could exist between the component parts and the whole.

17 An example of human social mosaics can be found with games and playing where humans display behaviour both juvenile and playful, as reported by the present author[49]. We shall quote a book on rugby written (in French) by Christophe Schaeffer: *Le Rugby expliqué à mon fils ou l'art de rester lié* [Rugby explained to my son or the art of bonding[50]]. While the book obviously has no specific reference to the mosaic model, the overall argument could be presented in terms of mosaic structures. Schaeffer notes that a rugby match needs harmonious integration of all players and compares the team to the parts of a house, the house being as big as the world[51], with the component elements spatially juxtaposed and functionally integrated, from the foundations (the forwards) to drafts of air rushing through (the wings). Every member of the team must make a distinctive contribution and provide what is required of him[52]. At the level of the *tesserae* comprising a mosaic, the difference is what makes teamwork so productive, whether in society or a rugby team[53]. "The difference between people is creative of life and joy[54]." Teamwork is what is being celebrated, and no matter what happens, through bonding the individuals remain together[55]. We have chosen the example of rugby, but many other sports and games played by humans could provide examples of mosaic organization in a social context.

18 On a more philosophical level, we can refer to the theses of the Japanese philosopher Naoshi Yamawaki[56] who has endeavoured to establish transnational public ethics. Initially this may appear to be substantially different from the present author's biological approach. Yamawaki argues that his ethics cannot be determined by either local or global considerations and has coined the term "glocal" to describe the "correlation between the global character of the problems and the culturally and historically defined locality where each human being lives" (p. 198), noting that "global and local perspectives are interdependent" (p. 198). The dialectics of the whole and its parts, when seen in the context of human civilization, can stand as an excellent example of integration between different levels of complexity, as proposed here for living beings. At the same time, this approach is in line with the idea that laws of the (biological) microcosm could also play a useful role in the (moderately) macroscopic social field.

Dialectics

19 The dialectics of the whole and the parts leads to the original concept of dialectics, dating back to ancient Greek philosophers and developed in its modern form by Hegel,

applying it to the mind, and by Engels and Marx applying it to the realm of material events (dialectical materialism). The concept of dialectics is based on a series of contradictions between two opposing processes (thesis/antithesis), thesis and antithesis being at the same logical level (Hegel) or material level (Engels), or juxtaposed in the mosaic model. The contradiction is then solved or overcome (synthesis); in other words there is integration of the two opposing processes, those processes being the parts, while the synthesis becomes the whole in the mosaic model.

20 The major philosophical concept of dialectics will be pursued (see chapter 4), because not only does it fit the mosaic model, but it also brings a new philosophical dimension to the model.

Ethical stances

21 Another domain of philosophy where the mosaic model can be useful is ethics.

22 The French philosopher Vanessa Nurock[57] has argued that ethics can be seen as a construction of three juxtaposed processes: agentive empathy (putting oneself in the position of another being), emotional empathy (simulating the feelings of another being) and situational empathy (understanding the cognitive situation of another being's life and behaviour, also known as the Theory of Mind). Integration of the first two processes can produce a basic concept of ethics, while full integration of all three processes can produce full-scale human ethics. Looking at certain disorders in humans, some of these processes may be seen to be absent: autism might involve a deficit in situational empathy, while certain psychopathic disorders could involve a deficit in agentive and emotional empathy. When using the mosaic model, further (sub)levels could be added. For example[58], the first agentive level may be the initial result of two or more units being juxtaposed: the sense of what the right action is (putting oneself in the place of the other person and considering the other person's well-being) plus the sense of justice (putting oneself in the place of the other person with consideration for cooperation and/or reciprocal actions). Looking beyond the cognitive architecture of morals to see the practical applications, Corine Pelluchon[59] endeavoured to integrate three separate and juxtaposed moral stances: human ethics, animal welfare ethics and environmental ethics, proposing "vulnerability ethics" meaning that human beings have a clear moral responsibility towards all other beings, including non-human species and ecosystems. This is mosaic integration of conventionally juxtaposed moral duties.

Literary approaches

23 Literary approaches too can be analyzed in terms of mosaics and a number of examples[60] will be cited.

24 "*Le Rayon du bas*" (The bottom shelf)[61] is a contemporary French novel by four female writers. The story follows four main characters whose lives and relationships are described over four seasons in the imaginary town of Belvais (referring to the real French town of Beauvais). The central plot is "the book" as suggested by the title which is the bottom shelf of a bookcase. The novel explicitly mentions four books (quoted with reference details) but indicating which character is linked to which book. *Tesserae*

can be identified in the plot development for, as is the case with many modern novels, the plot develops like a jigsaw puzzle with the reader having to gradually integrate the relevant information.

25 In the case of poetry, modern verse often combines different images in a semantic mosaic structure, but enhanced by various writing processes. Striking examples can be found in Japanese poetry.

26 A traditional haiku is a sequence of three verses of five, seven and five feet. The example I have chosen is a haiku written by the French poet Jean Monod[62].

> *L'absente de tout*
> *bouquet la voilà me dit*
> *en se montrant l'aube*
>
> *(Absent one from all*
> *bouquet here she is*
> *says dawn appearing).*

27 At the end of the first verse, the reader assumes the poem is about a human being (in French, the feminine gender suggests it is a woman); by the end of the second verse, it is about a flower (also feminine gender), but it is not until the last verse that the complete meaning, *i.e.* the whole, can be grasped: the image being conjured up is of dawn breaking, an image expressed with poetic references evoking a female being or entity and a flower. Finally the whole haiku can be understood as a harmoniously integrated mosaic of the different semantic parts of its three verses.

28 The Japanese renga (or modern version known as renku) can also provide examples of mosaic structures. It is written by two or more authors answering each other in alternating triplets (haikus) and couplets (distiches) with one author answering the preceding stanza. The poem soon becomes a striking series of different mosaic-like images[63].

29 Another classical Japanese form is the haibun, alternating short prose sections and haikus, and usually written by one poet. An initiative by the French poet Danièle Duteil (Association Francophone de Haibun) produced the "linked haibun" written according to the same principles as the renga[64] with several authors answering each other on the question of where does the sea start, alternating prose sections and classical haikus in an original mosaic construction.

30 Another original venture in poetry appeared in the French magazine *Jointure*[65] and featured a "combined poem". The idea was to collect short poems by many different writers and organize them into four sections dubbed (with humour in French) Thesis, Antithesis, Parenthesis and Synthesis. The work was thus a mosaic with the original short poems as the *tesserae*.

31 One final example here is from Hedi Bouraoui, a French-speaking author of Tunisian descent now living in Canada. He wrote a work that he described as a "narratoem[66]", *i.e.* a combination of narrative prose and poem. The story is about a Laotian girl who migrates to the west and befriends a Tunisian living in Canada. The *narratoem* is a fascinating mosaic combination of different literary forms, rendering the blending of cultures (Asia, Europe, America and Africa) as experienced by the protagonist. Hedi Bouraoui's work displays a harmonious combination of *tesserae* from the real world and *tesserae* from the realms of the imagination.

32 These are only a few examples of literary work being analyzed as mosaic structures, with different topics and different styles combining (integrating) as *tesserae* in a mosaic and leading readers to new and fascinating discoveries and feelings.

Relationships between Mind and Matter

33 The identification of processes in the structure of living organisms and in the structure of the mind can lead to further philosophical considerations. Many philosophers have investigated relationships between mind and matter. Hans Jonas[67] sees elements of the mind already present in the tiniest quantity of matter. The French philosopher Raymond Ruyer[68] argues that the concept of objective information is incomplete and that a conscious "I" is needed to endow any piece of information with its full meaning. Following this idea, Ruyer avoided a misleading dogma in modern biological literature which identifies information with negentropy: as a conscious "I" is needed to handle information, the concept of information could not, according to Ruyer, be reduced to a simple physical dimension such as negentropy.

34 More recently Hisaki Hashi[69] developed similar ideas and related them to Aristotle's philosophical arguments. She argues that nothing comes from "a merely functional set of information[70]", but rather needs "the next act in self-consciousness, oriented to understand this *bit of information*[71]". She sees the important relationship between information and consciousness as rooted in Aristotle's orientation "towards cognitive and analytical way of thinking in reality[72]". These philosophers bring a metaphysical dimension to the direct analogies which I have presented as mosaic structures, with parallels between organisms and thought processes, between body and mind. Without venturing here into the mind-body dilemma, we can say that these considerations give some strength to likely analogies between both fields – body and mind –, especially in the manner complexity is built.

Partial conclusion

35 The present chapter has shown examples of rules governing the complexity of living beings according to the principles of juxtaposition and integration and leading to mosaic structures can apply to other fields: memory, consciousness, language, drawing, music, technical objects, urban planning, mathematics, social structures, dialectics, ethical stances and literary approaches. This provides evidence that the mosaic model can have a wide range of uses beyond its original source in the anatomy of living beings.

NOTES

31. Chapouthier 2006.

32. Iglóia *et al.* 2010.
33. Delacour 2001.
34. Robert 2013.
35. Givón 1998.
36. Hombert & Lenclud 2014: 257.
37. Wang 2007.
38. Baldy 2011.
39. Heiser 2012.
40. Chapouthier & Kaplan 2011.
41. Oudeyer 2015.
42. Laming 2015: 59.
43. Tasic 2013.
44. Tonnelier *et al.* 1999; Ben Amor *et al.* 2010.
45. Ben Amor *et al.* 2010.
46. Ugolev & Ivashkin 1992.
47. Guja 2008.
48. Sorokin 1965.
49. Chapouthier 2009b; Morris 1967; Tinland 1977; Chapouthier & Policar 2015.
50. Schaeffer 2012.
51. Schaeffer 2012: 61.
52. Schaeffer 2012: 40.
53. Schaeffer 2012: 41.
54. Schaeffer 2012: 108.
55. Schaeffer 2012: 109.
56. Yamawaki 2009: 198.
57. Nurock 2011.
58. Nurock 2012.
59. Pelluchon2011.
60. All examples from Chapouthier 2013.
61. Leguay-Tolleron *et al.* 2013.
62. Antonini 2003.
63. Sato 1983; Shirane 2012.
64. Antonini *et al.* 2013. Text written in Folkestone (GB) in 2013 by a group of British and French poets including: Jean Antonini, Danyel Borner, David Cobb, Paul de Maricourt, Danièle Duteil, Georges Friedenkraft, Hanne Hansen, Meriem Fresson, Lynne Rees & Claire Wright.
65. Friedenkraft 1993.
66. Bouraoui 2012.
67. Jonas 2001.
68. Ruyer 1968.
69. Hashi 2011: 105-115.
70. Hashi 2011: 114.
71. Hashi 2011: 108.
72. Hashi 2011: 111.

Chapter 3. From Nature to “Culture”

1 In the first two chapters we presented evidence of general principles involved in complexity as mosaics as seen in very different fields. It is interesting to observe that the two distinguishing features which are the pride of the human race, *i.e.* the brain and highly complex thought, are built on the same foundations as the rest of the living world – juxtaposition and integration.

2 In the present chapter, I shall analyze the comparison in terms of nature and culture, with the brain referring to nature and the mind referring to culture. English-speakers often make the distinction between nature and nurture, but I prefer to use the continental word “culture”, for both humans and animals. The discussion in the previous chapter included phenomena of the mind such as language, music, drawing, philosophy and literature, and was already what I consider to be a cultural approach. The present chapter will address culture not simply as a human process but will also include cultural traits observed in the animal kingdom. However, to distinguish sophisticated human skills from often simple cultural traits in animals, the term “protoculture” will occasionally be used to designate certain cultural phenomena displayed by animals. I shall also argue that, contrary to certain traditional assumptions setting nature in opposition to culture, culture is actually the logical progression of natural processes. My argument will be backed by evidence to show that both nature and culture have the same basic processes, and that they are mosaic and triune processes.

Culture as opposed to nature

3 Human beings, with the impressive activity of their brain, have developed sophisticated cultures. A culture can be defined as a sum of behavioural traits which cannot be transferred by purely genetic processes, but include transfers through imitation or teaching among individuals. Human cultures involve technical skills and language. One specific feature that is important for the development of human societies and that should be noted here is that humans can record their knowledge and the pool of knowledge of a given generation is therefore greater than it was for the previous generation; human knowledge is thus cumulative and increases exponentially with time. While some animals can teach certain cultural phenomena to their offspring,

this is not comparable to the passing on and vast increase in knowledge from generation to generation for the human species. This increase is in the time context of history and is specific to the human species. Our prehistoric ancestors *sapiens sapiens* may have had the same exceptional brain activity as modern humans, but did not develop computers or sophisticated surgery. Similarly, feral children raised by animals, *i.e.* outside the framework of modern civilization, would not develop traits of modern human culture such as language or sophisticated technical skills.

4 Since prehistoric times, humans have used their cultural abilities as part of the Darwinian "struggle for life" to defend themselves against their environment, *i.e.* being opposed to nature. Many authors have developed arguments based on human) culture being *opposed* to nature. In prehistoric times, stones were shaped to cut plants and kill animals which are all part of nature. Modern agricultural tools and hunting weapons can be seen as an extension of these stones. The idea that emerged was that key characteristics of human society were cultural and in opposition to plants and animals, in opposition to all other living species – nature – and through evolution the human species had to fight for survival. Culture was thus a human prerogative and opposed to the natural environment. As human beings also had obvious animal traits (breathing, eating and reproducing), these traits were linked to nature and considered animal-like or bestial, set apart from the purely human status of culture. What humans had in common with animals (the natural side) was diametrically opposed to what was specific to humans (their cultural heritage). Humans were heroes of culture fighting and conquering untamed nature, not only in the animals around them, but also in their own animal nature.

5 The ecological and ethical repercussions of this anti-nature culture have been underlined by both political ecologists (focusing on the gradual destruction of the Earth and its natural biotopes, including the oceans) and animal rights advocates (speaking out against the disastrous way humans treat and cause suffering to our animal cousins). The anti-nature stance prevails in the western world with ideas developed by Descartes and his school, such as the unfortunate Malebranche who claimed that only humans had a soul and that animals were merely machines. The favoured position of humans then easily went from disregard for animals to complete and brutal domination of the natural environment, as chosen by the western civilization in the past century, polluting and damaging the earth.

Culture as part of nature

6 A closer examination will show, however, that culture is not necessarily set in opposition to nature and does not necessarily lead to such a disastrous anti-ecological position. Culture can also arise from nature, and in many fields culture is an extension or enhancement of activity in nature. This can be seen in both human cultures and more recent observations of animal cultures.

7 Let us start with human beings. It can be seen that many technical skills developed by humans are actually extensions of abilities already present in physical organs. Agricultural tools (scythes, sickles and axes) or weapons such as clubs and spears are extensions of what can be done, less successfully, with hands and arms. With the development of writing and painting, humans were able to extend memory beyond its

natural limits. Now computers simulate and extend the performance of the human brain; loudspeakers extend the power of the human voice.

8 In nature we are born as "naked apes" to quote the title of the famous book[73] by Desmond Morris. The human body looks like the foetus of an ape, with a larger head, big eyes and a mostly naked body (except for some hair on the head, sparse body hair and whiskers for males). Nature gave us the status of a naked ape, but this was not sufficient for the human mind. Humans devised and crafted tools, including blades for knives and razors, to extend and/or enhance what nature produced, *e.g.* to cut hair and shave whiskers and even body hair. Such cultural behaviour is designed to extend our natural traits.

Animal (proto)cultures

9 Several cultural traits have been observed in animals[74], which means that the concepts of culture and cultural traits cannot be considered as solely human, but have their roots in the animal kingdom. As such animal cultures are far removed from the complexity of human cultures (as stated above) I have chosen to use the term "protocultures[75]", even though some specialists disagree with the term[76]. The philosopher Gilbert Simondon[77] considers that while animal cultures exist, they cannot progress as much as human cultures because there has been no merging with technical thought. Simondon's position is therefore in line with my concept of animal cultures as protocultures.

10 The first report of animal (proto)culture dates back to 1952, in Japan, and Kinji Imanishi. On the island of Koshima, scientists a fed troop of macaque monkeys, giving them sweet potatoes on the beach. The potatoes were therefore covered in sand, so a young female got the idea of washing them to avoid biting on the grit. Over the years, this behaviour pattern was gradually adopted by all members of the troop and then passed on to the next generation[78].

11 Since this initial discovery, a number of cultural traits have been studied in animals, mostly mammals and birds[79]. Animals can use tools, cognitive rules, communication and language, and can display forms of moral behaviour and aesthetic choices

12 There are many examples of animals using tools: thrushes use "anvils" to break snail shells; woodpeckers have their anvils to break nuts; Galapagos chaffinches use cactus thorns to fish insects out of holes in cactus plants; one Australian bird colours its breast with grass to attract the females. Chimpanzees use twigs to extract termites from a termite mound: when the termite bites the twig and is attached to it, the chimpanzee removes the twig to eat the insect. Chimpanzees can also break nuts on stone anvils using a special technique, and observations of a chimpanzee population have shown that the technique is passed on from parents to offspring. Chimpanzees even invent "metatools" (tools used to make another tool), *e.g.* if a stone used as an anvil is unsteady, a chimpanzee can look for other stones to wedge under the first stone. Even crocodiles have been shown to position twigs on their snout to catch birds looking for twigs for their nest. Nest building is a good example of many animals, in particular birds and mammals, using tools; and social insects, *e.g.* ants in fungal growth on leaf-mould, use tools.

13 *Cognitive rules* have been reported in practice by many species, ranging from vertebrates to molluscs, such as the octopus family. Rats have been trained to master a simple rule such as: "I should match a box where I can find water with a similar box that I have seen just before"[80]. Dolphins can learn movements by following instructions given by humans. Many animals can grasp the concept of numbers and count up to six or seven. Pigeons have been reported to understand the idea of a forest or source of water. They have to pick a key to obtain food only where on a slide is presented, for example, a stretch of water, whether it is a sea, a pool or a river. If they pick the key when is displayed a slide with no stretch of water, they will not receive any food for this slide. Pigeons learn very well to pick only with the proper slide.

14 The jay can match geometrical shapes in a logical sequence, as in IQ tests. The great spotted woodpecker can anticipate the effects of the law of gravity, knowing when an object is about to fall. The American scientist Irene Pepperberg reported impressive behaviour by parrots, observing that they can sort objects according to colour and/or shape, according to whether they are similar or different. Let us finish with a social rule: the proscription of incestuous behaviour is not specific to humans but common, at least, among all primates.

15 *Communication* between animals can be extremely sophisticated, with many different types of communications: olfactory, electric (in water environments), acoustic, visual and tactile. Well known examples of acoustic communication are found with birds and whales. Reports have shown that certain birds can teach a certain way of singing to their offspring, creating song "dialects" and producing a cultural trait. Ethologists distinguish language from communication. Communication, even in the most sophisticated bird songs, conveys information that always refers to the present in the immediate environment of the animal communicating, *e.g.* the bird singing. Expressed as words, it may mean "This is my territory" or "I'm hungry" or "I want to mate" or "Beware! Danger!" Warning or danger signals can sometimes be understood by animals of another species; a bird may sound a warning when noticing birds of prey, and the entire forest may fall silent, suggesting that other birds and species have understood the message. But there is no information referring to anything that is no longer present in the immediate environment; there is no information referring to a past situation. However, language for ethologists, can communicate references to the past, to events no longer in the environment of the animal communicating.

16 Very simple *language* has been reported in bees. A bee which has found a food supply goes back to the hive and, by a characteristic dance, is able to communicate to other bees the direction and the distance to the food source. This is basic language with few "words" and no grammar. Humans can teach more complicated languages to chimpanzees and gorillas, but as they do not have the oral skills required for human speech, the languages used are either sign language as used for deaf mutes or arbitrary pictorial expressions on a computer screen, *e.g.* a black square for an apple and a red triangle for a banana. In such cases, apes can master a few hundred words and simple grammar rules and may sometimes teach them to their offspring. No evidence has been found of the use of similar languages by apes in the wild; such simple language communication has only been acquired through contact with humans. It may also be noted that human children do no acquire language spontaneously if not in contact with humans. Children raised by animals do not learn to speak

17 Interesting studies of dogs show that while they obviously cannot speak, they can, to a certain extent, understand human language, with some able to distinguish the names of more than one hundred different objects. Dogs were trained to distinguish different objects, *e.g.* a bone and a toy, and trained to act according to different verbal orders such as: “Get the bone” and “Sit next to the bone” or “Get the toy” and “Sit next to the toy,” showing that the dog discriminated between an object (noun) and an action (verb).

Proto-morals and proto-aesthetics

18 All animals live in societies or families, the family being the basic form of social organization, and they need to follow social rules that forbid certain acts which would disturb the harmonious functioning of the group. Members of a given group cannot fight if the fight exposes the group to danger from predators; offspring have to obey their parents. Such social rules are described here using the term *proto-morals.*

19 Proto-morals are very general rules and can also be found in human communities. Two examples will be given. All animals raising their offspring need to protect their young. This is a very general Darwinian rule, and can be seen, for example, with humans who refuse to tolerate torture and consider that it is more reprehensible to torture a child than an adult. A less general rule is the avoidance of incest by all primates. Cats and mice mate with directly related members of their group, but apes avoid incest. Human morals refusing incest go back to our identity as primates, as cousins to apes.

20 Frans De Waal studied captive populations of chimpanzees[81] and described examples of proto-morals. He observed behaviour patterns displaying sympathy, attachment, care for the young, help for disabled subjects, punishment, negotiation, cooperation and reconciliation, all behavioural phenomena that we could describe as morals. “Forgiving, remarks De Waal, is not... a mysterious and sublime idea that we owe to several millenniums of Judeo-Christianity. The mere fact that monkeys, apes and men all show reconciliation behaviour means that forgiving is probably more than thirty millions years old and that it is earlier than the separation which took place in the evolution of primates”.

21 *Aesthetic preferences*[82] are usually based on the physical characteristics of the sexual partner. If the partner is red and yellow, the animal will tend to prefer red and yellow. In human society, certain aesthetic choices could be described as sexual if gauged according to the number of naked bodies in paintings and sculptures.

22 Most animals prefer bright primary colours, symmetrical lines and curves, and a tune or beat when they sing (*e.g.* the singing of birds and whales). Kinaesthetic similarities can be observed in dances by humans and birds. Drawings by a chimpanzee are similar to drawings by a three-year-old child: in the centre of the page, with bright colours and continuous rather than broken lines. This suggests that similar aesthetic preferences can be found across the animal kingdom.

A philosophical expression of the relationship between nature and culture

23 One of the most interesting philosophical approaches here is the work of the Czech philosopher Josef Smajs[83] who considers that there are two different ontic orders, or two different ontic layers: natural and cultural. Smajs speaks (somewhat ambiguously) of orderliness: "cultural orderliness is an orderliness with a different organization than that of nature[84]". While culture evolved from nature, it has become, at least in human culture, anti-nature, as discussed above: "The current antinatural culture irreversibly destroys those natural forms on which it depends[85]". There is a human "cultural evolution against the old, evolutionary-constituted structures of animate and inanimate nature[86]". Smajs believes that to counter the dangerous move by humans against nature (one of the central topics of modern political ecology movements), we must achieve a new "biophilous culture". "A real planetary solution [...] would be based on the absolute priority of a sustainable habitability of the Earth for the first time, namely on a biophilous cultural strategy[87]". By focusing on the animal side of humans, we could, to quote the French geneticist André Langaney, "be animals and proud of it[88] ". If we retrieved our natural ontic layer as animals, we would probably adopt the biophilous attitude making it possible to transform the earth into a sustainably habitable planet.

Nature and culture against entropy

24 The second law of thermodynamics says that all material systems tend to reach a poor state of energy called maximum entropy. Expressed differently if not completely accurately[89], it could be said that all material systems tend to maximum disorder. But the work of modern scientists in the field of thermodynamics, names such as Ilya Prigogine and Jacques Tonnelat (see chapter 1), shows that there are some remarkable exceptions to this general law. When a system can accumulate matter and energy locally, in situations far from energetic equilibrium (open non-equilibrium situations known as "dissipative structures"), this can reverse the entropic path and reach a decreased entropic, or negentropic, state. "The growth of natural orderliness under normal conditions is possible only in open non-equilibrium systems, in so-called dissipative structures", as observed by Smajs[90]. This is the distinctive case of living systems and organisms: "Evolution (...) proceeds 'against the current', against the tendency toward general decomposition[91]". The Slovakian philosopher Ladislav Kovàc[92] sees the negentropic path leading to a continuum between non-life and life. From this point of view, the very appearance of life is a correlate of the second law of thermodynamics according to which living structures, locally, in non-equilibrium situations, are able "not only to maintain their onticity but also to grow in size, to break up to give rise to self-similar structures[93]". Darwinian theory in the broadest sense can now be seen as the reverse side of the second law of thermodynamics: permanently opening towards locally non-entropic oriented structures, "a dynamic process of generation of structures and of massive self-organization[94]." Such oriented evolution leads to more complex structures.

25 Culture has taken over from nature. While within non-equilibrium situations, negentropic paths tend to oppose the general (entropic) path of the universe, and while

biology may appear as a rebellion against the second law of thermodynamics, then culture does the same at an intellectual or cognitive level. As previously stated, culture tends to be in opposition to nature, and we expanded on this idea following work by Smajs (cited above). This tendency of human culture and its practical, social and ecological effects obviously cannot be ignored. Yet when seen from the entropic point of view as discussed here, the situation appears to be quite different, or even the opposite, for culture enhances, in its own way, biological endeavours initiated by nature. Culture is an extension of nature. Tools re-used to enhance the physical abilities of the body. Communication and language enhance interactions, chemical or other biological phenomena which have always existed. Cognitive rules and declarative memories[95] enhance the abilities of animals to be autonomous and thus enhance the function of basic procedural memories (or unconscious habits) first developed in lower organisms. Social communities with social and moral rules make it possible for groups of organism to behave consistently and for biological systems to reach higher levels of organization or complexity, with greater autonomy. Aesthetic choices too can increase an animal's ability to choose between different behaviour patterns and have greater autonomy.

26 Living beings follow a negentropic pathway, both naturally and culturally, throughout their life. They may seem to rebel against or oppose general laws of nature such as the ubiquitous second law of thermodynamics, but this is just a façade of rebellion. As Prigogine and Tonnelat have shown, this negentropic pathway can be explained by a local accumulation of matter and energy by dissipative structures and this remains consistent with the general functioning of the universe. Once living beings die, they stop accumulating matter and energy, and as inert objects then return to entropic evolution.

27 This original situation of biological nature and culture may explain why both processes seem to function the same way. Here we find a thermodynamic correlate of what was stated earlier, *i.e.* that the complexity of living beings at both natural and cultural levels is built as mosaic structures, the mosaic architecture of complexity fitting both the natural and cultural processes underlying living organisms.

Cultural traits as mosaics

28 The examples presented have shown that cultural traits are not solely the prerogative of mankind, and that some can be observed in the often complex behaviour of (other) animals. Cultural traits displayed by animals are usually simpler than cultural traits developed by humans, *e.g.* language, complex machines, works of art and moral treatises, hence the use of the concept of proto-culture to describe cultural traits for animals.

29 These include, as mentioned above, the use of tools, cognitive rules, communication and language, proto-morals and proto-aesthetics. While an in-depth analysis of the construction of these behavioural traits cannot be undertaken when investigating animals (as it could for human language), it can be stated that all and any of these traits are the result of the juxtaposition and integration of basic segments of behaviour. Breaking a nut, for example, requires the juxtaposition of several behavioural units or actions as part of an integrated movement designed to perform the task successfully. Similarly, mastering cognitive rules, communication and language (*e.g.* human

language) is the result of the juxtaposition and integration of cognitive elements leading to an efficient sequence. The same is true for the cognitive and/or behavioural segments needed to express (proto)moral rules and (proto)aesthetic choices. In all such (proto)cultural situations for animals (as is the case for cultural traits described above for humans, and as has been shown with the example of human speech constructing of a meaningful sentence), the complete action by the animal accomplishing cultural behaviour requires the juxtaposition and final integration of elementary behavioural and/or cognitive segments.

Partial conclusion

30 The first two chapters presented evidence of the mosaic model applied to the anatomy of the brain (a natural element) and to components of the mind (memory, consciousness, language, literature, and philosophy), all elements related to culture. The present chapter has focused on nature and culture. Despite the view of nature being diametrically opposed to human culture, they have been seen to be a continuum, with culture extending what nature had started. It is therefore not surprising that the same processes seen with the mosaic construction of complexity can be found in both fields. This supports the hypothesis that these same rules can apply in different areas of the cosmos. Though, technically, nature and culture cannot be considered one as microcosm, the other as macrocosm, they still belong to two very different ontic levels, thus extending the Aristotelian belief in the universality of biological processes to these ontic levels, with complexity of culture being built according to the same processes as apply to complexity in living organisms.

NOTES

73. Morris 1967.
74. Chapouthier 2009b.
75. Chapouthier 2009b.
76. Lestel 2001.
77. Simondon 2008.
78. Imanishi2002.
79. Lestel 2001.
80. Alexinsky & Chapouthier 1978.
81. De Waal 1989; De Waal 2006.
82. Kreutzer and Aebischer 2015.
83. Smajs 2008.
84. Smajs 2008: 144.
85. Smajs 2008: 67.
86. Smajs 2008: 145.
87. Smajs 2008: 196.
88. Langaney 1991.

89. Matras & Chapouthier 1984.
90. Smajs 2008: 81.
91. Smajs 2008: 109.
92. Kovàc 2015.
93. Kovàc 2015: 13.
94. Kovàc 2015: 20.
95. Schacter 2001.

Chapter 4. Mosaic Theory: from biocosmology to dialectics, A biocosmological perspective

1 Over a number of years, Konstantin Khroutski and his colleagues in Russia have been developing a neo-Aristotelian Biocosmological philosophical stance, focusing, *inter alia*, on Aristotle's idea that the laws of the microcosm mimic the laws of the macrocosm. In this context, the word Biocosmology is usually written with a capital letter to distinguish the philosophical approach from experimental biocosmology, *i.e.* the bid to find evidence of extra-terrestrial life, including the possibility of intelligent extra-terrestrial life. In other words, we are speaking of the approach Aristotle applied to the universe as organic, or biological in modern terms, rather than physical. Aristotle's universe is one whole organic cosmos, every entity of which is subjected to purposeful forces that are basically the subject's *causa finalis* and *entelecheia*, and are ultimately ruled by the Nous – cosmic logos. Place and function are inherent, playing a part as an entity (microcosm) in one whole macrocosm.

2 In a modern perspective, the Biocosmological philosophical stance leads to the hypothesis that the laws of complexity which rule the complex systems found on our planet, *i.e.* the living beings, could also be considered as general laws for complexity everywhere in the universe[96]. From this point of view, the mosaic model presented in the two first chapters fits this philosophical stance very well. As stated by Arthur Saniotis, the mosaic model "is holistic and non-reductionist, recognising that biological and cosmic processes follow Aristotelian causes."[97] As the mosaic model based on observations of living organisms can also be applied, as we have seen, to many areas in psychology, linguistics, sociology and philosophy, the model could also be considered a good candidate as one of the main elements in the Biocosmological approach. Following what we call the Aristotelian-Khroutskian stance, we can speculate that the structure of complexity and its construction through juxtaposition and integration (as defined here for biological entities with the whole not cancelling the autonomy of the parts) might also apply to other entities in the universe. The focus of Chapter 5 is on this Aristotelian concept, presented with more concrete arguments.

3 The Biocosmological approach goes further, and the present chapter will present another element in the approach: the architecture of living beings as triune entities. We will show that this leads to the classical philosophical concept of dialectics, presented above as a possible extension of the mosaic model.

Triunity in living beings

4 It has been argued that triunity may be an elementary process in the functioning of organisms. Khroutski[98] cites a number of biological examples of triunity in living beings, *e.g.* the sleep-wake cycle, systole/diastole and the "(one) vegetative (super) system: the parasympathetic, sympathetic and metasympathetic (sub)systems[99]". It may be noted that western medicine is largely based on simple dichotomies, distinguishing the sympathetic and parasympathetic systems, and has therefore tended to overlook the autonomous action of the "free ganglia" in the metasympathetic system; these govern, for example, the beating of the heart, a continuous and spontaneous activity not requiring any action from the sympathetic or parasympathetic systems and which, to a certain extent, integrates occasional, opposite actions from the sympathetic and/or parasympathetic systems. Similarly, between sleep and wakefulness, there is a state of waking with the possibility of the concomitant existence of both "poles", even though they may appear alternately. This can be seen as an expression of the "law of polarization" as defined for sociocultural processes by Pitirim Sorokin[100] (mentioned in Chapter 2) with his contribution to a new, mosaic-like sociology.

5 I maintain that for biology, such triunity may be much broader in scope, provided that it is linked to changes in metabolism occurring with time and ultimately leading to the ontogenetic development of living beings. Here again a modern scientific approach would first focus on the dichotomy between two opposing entities, *e.g.* opposite reactions in a biochemical equilibrium, these being the permanent bases of cellular metabolism, *i.e.* of life, and also, at a more integrated level, the opposition between release and inhibition regulating hormones, or the two hemispheres of the brain and their effects on the behaviour of higher animals. Simplicity prevails and binary division is commonly found in living beings. The physical movement of animals involves a right and left side in an approximately symmetrical arrangement, leading, in some cases to two symmetrical brain hemispheres.

6 However, the focus on two opposing actions overlooks the later stage in time when such actions achieve balance, and in the subsequent stage of ontogeny when the two opposing actions produce a more stable state, "overruling each other by turns[101]", reaching a state of "oneness of the two autonomous poles (bipolar unity[102])" – a temporary, conclusive and unitary stage of the opposition, creating a triadic unity which may become the point for further triadic developments.

The Dialectical Roots of Triunity

7 Triunity may be considered as a development arising from the philosophical concept of dialectics. It can be applied to both the field of the mind and, more generally, the material world. For the mind, it refers to Hegelian movements of thought. For the

material world, it refers to material movements as first described by Heraclitus in ancient times, and to the limited scope of natural dialectics and the over-simplistic examples presented by Engels in his "*Dialectics of Nature*". Engels, with the limited biological knowledge of the time, measured physical phenomena such as movement, tides, heat and electricity, producing arguments for the dialectics of nature which are relatively unconvincing. Biological examples such as the complex ontogeny of living beings or the evolution of species or, as mentioned earlier, the numerous reactions of cellular metabolisms, could provide clear and strong arguments for the triadic development of the biological and terrestrial phenomena in the universe. Triadic development is better suited as a prerequisite for dialectics as argued by Hegel, but is applied by Engels to the physical side of nature instead of thought. This is a critical point as it makes it possible to link modern neo-Aristotelian stances with Hegelian dialectics. It has already been stated that dialectical movement can be understood as a mosaic system, being based on a series of contradictions between two opposing processes (thesis/antithesis), which can be considered as juxtaposed, while contradictions are being solved and overcome (synthesis) in what can be considered as an integration of two opposing processes. This architecture, which is in line with the architecture of the mosaic model, can be found in the logical dialectics of Hegel as well as in the materialistic dialectics of Engels. The triune movement, as argued by Khroutski and proponents of neo-Aristotelian Biocosmology is also in agreement with the dialectical movement, thus giving a likely dialectical interpretation to the Biocosmological approach.

Biocosmological triunity and certain modern philosophical stances

8 It has been noted that some modern thinkers, both scientists and philosophers, could develop arguments that would fit perfectly into the mosaic model. On similar lines, I shall show that a number of modern thinkers have developed stances that can fit the triune Biocosmological viewpoint, even though such stances do not necessarily include all the laws involved in the neo-Aristotelian perspective, but simply express concepts which can easily rally with triunity; even in philosophical arguments, for example, with the theses of Lupasco who claims to be non-Aristotelian.

9 It may seem out of place to quote the Romanian philosopher Stephane Lupasco (1900–1988) who is known for his arguments for non-Aristotelian logic, but I maintain that his reasoning is neo-Aristotelian. In his book *The Principle of Antagonism and the Logic of Energy*[103], Lupasco questioned the *tertium non datur* principle of classical logic which does not leave any logical scope beyond the duality of being and non-being. Lupasco maintained that one phenomenon could simultaneously include both an action and its opposite, but he introduced a "third state" between the two opposing entities, going beyond the classical principle of duality, and defining something very similar to Konstantin Khroutski's triunity. Today Lupasco's work is little known, but I would advocate a neo-Aristotelian interpretation of his work. Lupasco's opposition to *tertium non datur*, with no scope beyond the duality of being and non-being, could be interpreted in a biological context as the equilibrium between two opposite actions producing a balance in the third stage of triunity; Lupasco is thus seen as having an Aristotelian view. A biological understanding of complexity, such as the Aristotelian

approach, would have Lupasco's apparent opposition to classical logic dismissed as a mere difference in expression.

10 Cherlonneix, a promising young French philosopher, is interested in processes underlying biological phenomena and in particular the philosophical consequences of apoptosis (programmed cell death), which has been shown by Ameisen[104] to be a necessary stage in the evolution and development of organisms. Cherlonneix conducted an in-depth analysis[105] of the opposing actions of apoptosis and its inhibition which he described as "a-death", or non-death. However, constant movements in metabolism, such systematic and opposite actions of death versus non-death occurring at the cellular level, must reach a stable third stage, even if only a transient stage, for living beings to develop their structures (as is the case with the mosaic structures according to my arguments). In other words, Cherlonneix's views could be a description of the basic processes of the dialectics of life, in which mosaic structures would be the third (transient and stable) stage which could be cited as further evidence for triunity being a valid model.

11 The works of Lupasco and Cherlonneix can be seen as presenting a triune basis for the emergence of such mosaic structures, thus bringing a (neo)Aristotelian approach to the dialectics of life.

Partial conclusion

12 Our model of complexity in mosaics can be quoted as a good example of the Biocosmological approach as developed by the Russian philosopher Konstantin Khroutski and the neo-Aristotelian school. Since the mosaic model of complexity can be applied to a great number of different fields, it may be possible to apply it to both macrocosmic and microcosmic entities. The same is true for triunity, another classical stance of the Biocosmological approach, it being the fundamental unity of a three components structure. The argument that biological structures are based on triune principles can be backed by clear examples seen in the metabolic activity of living beings; the argument can also be related to the classical (triune) dialectical movement: thesis, antithesis, synthesis. The triune structure of living beings can clearly be extended to apply to different fields both at the materialistic level (in line with Engels' "Dialectics of Nature") and at the ideological level (in line with Hegel's dialectics). The dialectical approach thus stands as a legitimate and correlated extension of our mosaic model and fits both macrocosmic and microcosmic entities. These considerations, as well as the work of philosophers such as Stephane Lupasco or Laurent Cherlonneix, lead to a neo-Aristotelian approach to the dialectics of life.

NOTES

96. Khroutski 2008; Khroutski 2010.

97. Saniotis 2013: 337.

98. Khroutski 2010.
99. Khroutski 2010: 70.
100. Sorokin 1965.
101. Khroutski 2010: 72.
102. Khroutski 2010: 73.
103. Lupasco 1951.
104. Ameisen 1999.
105. Cherlonneix 2008.

Chapter 5. Towards an extended Biocosmological Stance

1 This chapter will show how the mosaic model of complexity can be combined with two major philosophical stances: the (neo)Aristotelian tradition and the general theory of systems.

2 First we shall review statements made in the Introduction and Chapter 3. Aristotle argues that there is a strong relationship between the microcosm (the Earth) and the macrocosm (the heavens and the stars). For Aristotle, the architecture of the cosmos is the same as the architecture of earthly structures. As has been noted, this does not mean in modern terms that the cosmos should be seen as a giant ape like King Kong, but rather that the architecture of the cosmos is probably based on the same patterns or principles as the architecture of the most complex structures we can directly observe and analyze on Earth, *i.e.* biological structures. As has been explained, the stance known as Biocosmology or Neo-Aristotelism was developed by the Russian philosopher Konstantin Khroutski. The mosaic structures described in the present book could be likely candidates for elements contributing to this general architecture of complexity. The fact that the mosaic model can already be applied to a wide range of different earthly fields, such as biological systems, and also language, sociology, culture, literature, music, town planning and robots, could be strong evidence for a model that is valid in many areas of our microcosm, and could also be a relevant tool for describing areas of the macrocosm. A biological stance could thus lead onto a Biocosmological approach and prove to be a fruitful collaboration for both Biocosmology and biology.

3 This is in fact what was done by the French astrophysicist Jean Audouze[106]. In a recent book, Audouze presented a broad analysis of the architecture of the universe, from the atom to galaxies, and found strong parallels between the organization of the earthly microcosm and the organization of the cosmic macrocosm, pointing out the mosaic structure of heavenly bodies such as stars and galaxies. “Let us imagine, writes Audouze, that the Universe is an enormous Russian doll, from super-clusters of galaxies to objects of our terrestrial environment, passing through galaxies, stars and planets… Each of these structures is composed of all those of inferior rank of which they only partially share the properties, although it has been shown that the behaviour of the

biggest structure of the Universes indeed reflects in a way the physics of particles[107]". Audouze notes that all these structures "refer to the model of the mosaic, defined by Georges Chapouthier[108]". Audouze's work gives a clear response to one of the goals of the present book which is to identify processes underlying macrocosmic and microcosmic events and provide evidence for the Biocosmological stance.

4 We have observed that one of the bases of the Biocosmological approach is a triune process that we have linked to the philosophical concept of dialectics. Following ideas as argued by Audouze, the Biocosmological stance can lead to the conclusion that such triadic or dialectical movement is obviously not specific to living beings, but can apply to the complexity of the cosmos; or, stated differently, evidence for the triadic development of living beings can be used to predict triadic development in other entities of the cosmos. When expressed in dialectical terms, this is a way of suggesting that the dialectics of nature (obvious in the case of living beings) may extend into in other fields or even other parts of the universe.

> This (neo)Aristotelian stance can be seen in relation to the holistic "General System Theory[109]" developed by the Austrian philosopher and biologist Karl Ludwig von Bertalanffy as early as 1937. The theory is that similar principles can be found in different theoretical and/or scientific fields, or, alternatively, that models, principles and laws that can apply to general systems can be found in all fields of knowledge. The starting point for von Bertalanffy was biology and he followed a path somewhat similar to ours. As the mosaic model is in complete agreement with the Biocosmological approach, it may be considered as one of von Bertalanffy's very general principles, being found in a number of different fields of knowledge. Any analysis of the architecture of complexity should include an investigation of the juxtaposition of similar units and their subsequent integration in a mosaic formation that allows a certain degree of autonomy to the component parts. Or conversely, the mosaic model could be considered as one of the principles of a general system.

Against the "anthropic principle"

5 As this point, it is important to note that both Khroutski's stance and mine expressly preclude the possibility of evolution centred on humans alone, as in the notorious and anti-Darwinian "anthropic principle[110]" which sees complexity solely in the specific case of human beings and their highly specific world/environment, our world, our planet. According to the anthropic principle, evolution was intended to ultimately and specifically produce the human being. This is in contradiction with everything that can now be reasonably assumed about life in the universe. As the chemistry of carbon appears to be ubiquitous, and as organic compounds can be found in comets, it is likely that complex biological structures can be found in many parts of the cosmos and that we, humans the "naked apes," are a highly specific or unusual result of highly specific or unusual terrestrial evolution. Expressed in different form, the anthropic principle can be described as a revival of the old idea of mankind considering itself to be at the centre of the universe. Both Khroutski and I and are categorically opposed to the anthropic principle, it being an anthropocentric principle far removed from the Aristotelian cosmocentric approach.

Why knowledge is possible

6 These thoughts on complexity in living beings have a further and substantial epistemological effect that can be argued as a conclusion. If mosaic structures of life and their basic triune processes are models for the structures and triune processes of the entire cosmos, there is then a clear explanation of why the laws of the universe can be understood by humans, of why human (scientific) knowledge is possible. As has been seen, the most complex organ, the human brain and the mind processes which it controls (*e.g.* consciousness, language and memory), fits the theory of the mosaic model and triune processes of life and can therefore simulate or mimic laws governing the surrounding environment, which, for the Biocosmological hypothesis, are the same laws.

7 More specifically, as the central nervous system in living beings is part of the universe, it is able to understand the functioning of other parts of the universe which operate along similar lines. The simulation of the external world by the brain[111], which is already present in evolved animals such as vertebrates and cephalopod molluscs, reaches its highest point in the human ability to develop scientific knowledge of the world where humans live. In more philosophical terms, humans, as living beings, are determined by the four Aristotelian causes (material, formal, efficient and final), so it is only logical that humans should understand other systems in the universe which are determined by the same causes. Furthermore, complex species tend to cephalisation, *i.e.* concentration towards the top of the body, in the direction of movement, with the brain, a highly sophisticated organ, gathering sensory information and processing it in complex ways, including reasoning and memory[112]. Through this is a general process (found not only in vertebrates, but also in insects and molluscs), simulation of the laws of the universe by animals and humans becomes increasingly sophisticated.

8 As both the cosmos and biological systems are built in the same way through the same Aristotelian causes, they tend to achieve the same patterns of complexity, with parts of the cosmos (human brains) able to simulate and understand other parts of the cosmos. If, as stated by Khroutski: “human consciousness is exactly a means – a tool function[113] ”, then for cosmic evolution, there is an explanation of why human consciousness can understand the laws of cosmic evolution.

Partial conclusion

9 Our book was written in a Neo-Aristotelian and Biocosmological spirit, assuming that, according to Aristotle’s ideas, the structure of the macrocosm mimics the structure of the microcosm. The fact that similar principles (in this case our mosaic model with its principles of juxtaposition and integration) can be found in so many different fields, suggests there is common architecture throughout the material world. The best way of demonstrating this would be to directly show that macrocosmic events follow the same principles as microcosmic events, which is what the astrophysicist Jean Audouze did in his recent work, making legitimate use of the mosaic model applied to stars and galaxies, thus providing direct evidence for the neo-Aristotelian assumption which was our original hypothesis.

10 This leads us to make two key observations. Firstly, that our stance totally rejects the anthropic principle claiming that complexity ultimately leads only to the specific case of human beings and to their highly specific world/environment which is Earth. This absurdly anthropocentric view must be dismissed. It should, however, be assumed that complex carbonaceous structures similar to animal life but developing through specific evolution could well be in different parts of the universe. My second observation is on the way human knowledge can decipher and understand the world in which we live. The abilities of the human brain, from animal abilities, are built according to the same principles and rules as the rest of the universe, and because both the brain and universe are governed by the same principles and rules, the human brain and mimic or simulate the structures of the world and thus develop scientific knowledge.

NOTES

106. Audouze *et al.* 2015b.

107. Audouze *et al.* 2015b: 45.

108. Audouze *et al.* 2015b: 45.

109. Von Bertalanffy 1968.

110. Carter 1974.

111. Chapouthier 2008.

112. Chapouthier 2008.

113. Khroutski 2010: 72.

General Conclusion

1 What is complexity?

2 Here is the philosophical question raised in the introduction. In an Aristotelian spirit, I have endeavoured to present an answer to the question, starting with biological considerations and continuing through to philosophical stances. While I obviously did not intend to give a complete and universal definition of complexity, the present work based on the architecture and complexity of living beings has led to a number of conclusions.

A scientific quest

3 Complexity in living systems is based on two general principles: the juxtaposition of similar units and then, at a later stage, integration of the juxtaposed units to form structures at a higher level, the original units then becoming component parts of the higher structure. Examples of the processes have been presented, ranging from the organization of genes to the structure of animal populations, covering different levels, *e.g.* cells, organs, groups of organs known as metameres (the basic element in most animals) and individual organisms. We observed that, as is the case for art mosaics, living beings can be seen as mosaics, *i.e.* structures where original component parts, when part of a higher level structure, maintain independent properties and autonomous functions; expressed in different terms, they are structures in which both the parts and the whole can behave, at least partially, independently of one another. This is a practical way of describing the development and emergence of parts and the whole. Our model can be used as a biological approach to the emergence of complexity. The scope of the model was extended, as seen with examples featured in the first chapters. Further analysis provided evidence showing that within a given organism the development of organs as important as the brain also fits the mosaic model: the organization of brain vesicles, areas of the cerebral cortex and the two hemispheres of the brain stand as good examples of mosaic constructions. Thinkers such as Richard E. Michod and Stephen M. Modell in the United States have also proposed models for complexity that can fit our model.

4 The mosaic model is compatible with Darwinian natural selection based on sexual reproduction, and also offers an epistemological rehabilitation of the role of asexual reproduction, a basic process in the development of living beings dating back a long time but often overlooked as research focuses on sexual reproduction. In many cases anatomical complexity in animals can arise from non-separation of structures, *e.g.* cells or "twins" produced by the asexual separation of the fertilised egg into two identical units, and subsequently undergoing integration, in a mosaic formation. This is in line with the thesis advocated by Brazilian philosopher Paulo C. Abrantes who claims that during transitions from a lower biological level to a higher one, there is a process of de-Darwinization, for once the lower level has become part of a higher level, it is no longer governed by strict rules of Darwinian selection.

5 The mosaic organization of the human brain led us to investigate whether the mosaic model was compatible with and could be applied to human mind processes, and we found that the model can also be used to describe memory, consciousness, language, drawing, music, technical objects, urban planning, mathematics and information theory, social structures, dialectics, ethical stances and literary approaches. These are fields of activity for living beings (in this case, for human beings), and it is interesting to observe the same mosaic organization in so many different fields of human cultural activity no matter what the possible relations are between matter and mind, or between the brain and thought. The mosaic model was extended to cultural activities developed by animals other than human beings. Reports on cultural traits in animal groups provided evidence of the use of tools, cognitive rules, communication and language by different species. Practical, moral, behavioural and aesthetic choices were observed in animals, in particular in social species. It was seen that the mosaic model can be useful, not only to describe the complexity of the natural properties of living beings in areas such as genetics and anatomy, but also to help understand their cultural traits and to perceive the effects of mental processes.

Philosophical stances

6 The focus on biology was then followed by philosophical considerations. Our model of complexity in mosaics was presented as a good example of the Biocosmological approach as developed by the Russian philosopher Konstantin Khroutski and the neo-Aristotelian school. Since the mosaic model of complexity can be applied to many different fields, it may also be applied, as argued in the Aristotelian Biocosmological approach, to both macrocosmic and microcosmic entities. In biological systems, in addition to the different fields covered for the mosaic model, there is the concept of triunity as developed by Khroutski, the basic argument being the fundamental unity of a three-component structure, that can prove very useful for understanding the functioning of living beings. A number of examples were given, including metabolic activity in organisms.

7 Triune processes can also be seen as compatible with the general philosophical concept of dialectics, as basic dialectical movements (thesis, antithesis, and synthesis) are a triune construct. Living beings can be analyzed as a triune structure in different fields, at a materialistic level (as for Engels' "Dialectics of Nature") or an ideological level (for Hegel's dialectics). These considerations plus the work of philosophers such as Stephane Lupasco and Laurent Cherlonneix have led to a neo-Aristotelian approach to

the dialectics of life. The mosaic model can also fit von Bertalanffy's holistic General System Theory according to which similar principles can be found in different theoretical and scientific fields, and mosaic structures may be considered one such general principle. On the energetic side, mosaic models in living organisms are part of the general functioning of life, in both nature and culture, being dissipative structures able to stand as a local force against the ubiquitous evolution of material systems towards greater entropy, *i.e.* they can follow a negentropic path.

8 It is important to focus on the essential link between mosaics and dialectics. Mosaic structures, as observed in living beings, initially appear to be relatively static constructions. With our definition of them at different levels of living beings, ranging from cells to genes and populations, they are very useful for describing temporary states of a living system, even though, over time, living systems are never totally static; such static constructions can only be observed for a certain period of time. When extending the time period, living beings constantly change from birth to death, at the cellular level (metabolism) and at more integrated levels (ontogeny of organisms and phylogeny of populations or species). The logical complement to the mosaic model is therefore the dialectical process, also built on triune mosaics but clearly oriented in time, thus endowing mosaics with a temporal and evolutionary dimension.

9 Recent work by the astrophysicist Jean Audouze provided clear evidence for the relevance of the mosaic model applied to heavenly bodies, and therefore in the cosmos. His interesting discussion supports the legitimacy of the Biocosmological approach which is the basis for the present text. It is shown that the architecture of stars and galaxies can mimic the architecture of complex terrestrial living systems; it is shown that the macrocosm can, as argued by Aristotle, mimic the (biological) microcosm. Our mosaic model can play a key role in this process as it has similar principles (juxtaposition and integration) applying at both the macrocosmic and microcosmic levels. With the similarity of principles in both macrocosmic and microcosmic systems, our mosaic model can fit the General System Theory, with mosaics being a key player of such general systems. It may be deduced that living beings, (*i.e.* complex carbon-based systems) can be found everywhere on Earth and, quite probably, in other parts of the universe. The general architecture of mosaics, if applied to carbonaceous structures, could uncover similar organizational structures throughout the cosmos, not just locally on Earth, the third planet of our solar system.

10 On the one hand there is the world of living beings, their nervous systems and their ability to think, and on the other hand there is the cosmos with its organization built on mosaic formations; the similarity between the two may explain why the human brain can understand the material world and conduct and develop scientific activity. The cosmos and biological systems are built the same way, according to the same principles and the same rules. Biological systems, with no doubt the most complex structures on Earth with the central nervous system and the brain able to simulate the world, can simulate principles and rules of the physical world. The central nervous system can simulate and understand other parts of the cosmos, an animal ability developed powerfully in the human brain.

11 These contemplations of the complexity of living beings, of the brain and mind and beyond, of the complexity of the universe, can show that complexity is not necessarily as complicated as could be expected. Some properties can be observed and described as

simple processes: the process of juxtaposition and integration, and expressed as mosaic models.

Bibliography

ABRANTES Paulo C., 2011, « Culture and transitions in individuality », *in* Luiz Henrique de ARAUJO DUTRA & Alexandre MEYER LUZ (eds), *Temas de Filosofia do Conhecimento*, Florianópolis, Nucleo de Epistemologia e Logica (NEL/UFSC), p. 395-408
[Online: https://issuu.com/filosofia.ufsc/docs/rumos11].

ALEXINSKY Tatiana & Georges CHAPOUTHIER, 1978, « A new behavioral model for studying delayed response in rats », *Behavioral Biology*, 24, p. 442-456.

AMEISEN Jean Claude, 1999, *La Sculpture du vivant. Le suicide cellulaire ou la mort créatrice*, Paris, Le Seuil.

ANTONINI Jean (ed.), 2003 *Anthologie du haïku en France*, Lyon, Aléas Éditeur.

ANTONINI Jean *et al*., 2013, *L'Écho de l'étroit chemin* (Association Francophone de Haïbun), 8 [Online: https://issuu.com/kurokami575/docs/echoafah-8-hd].

AUDOUZE Jean, CHAPOUTHIER Georges, LAMING Denis & Pierre-Yves OUDEYER (eds), 2015a, *Mondes mosaïques*, Paris, CNRS Éditions.

AUDOUZE Jean, 2015b, « L'univers », *in* Jean AUDOUZE, Georges CHAPOUTHIER, Denis LAMING, Pierre-Yves OUDEYER (eds), *Mondes mosaïques*, Paris, CNRS Éditions, p. 15-58.

BALDY René, 2011, *Fais-moi un beau dessin*, Paris, Éditions In Press, coll. « Psycho ».

BEN AMOR Hedi, GLADE Nicolas, LOBOS Claudio & Jacques DEMONGEOT, 2010, « The isochronal fibration: characterization and implication in biology », *Acta Biotheoretica*, 58, p. 121-142.

BERINGER Elizabeth, 2010, *Embodied Wisdom: the collected papers of Moshe Feldenkrais*, New York, North Atlantic Books.

BOURAOUI Hédi, 2012, *La Réfugiée (Lotus au pays du Lys) (Narratoème)*, Toronto, CMC Éditions.

CARTER Brandon, 1974. « Large number coincidences and the anthropic principle in cosmology », *in* Malcolm S. LONGAIR (ed.), *Confrontation of Cosmological Theory with Astronomical Data*, Dordrecht, Reidel Publisher.

CHAPOUTHIER Georges, 2001, *L'Homme, ce singe en mosaïque*, Paris, Éditions Odile Jacob.

CHAPOUTHIER Georges, 2003, « GABA receptor subunits and global behaviour », *Drug Discovery Today*, 8/17, p. 778.

CHAPOUTHIER Georges, 2006, *Biologie de la mémoire*, Paris, Éditions Odile Jacob.

CHAPOUTHIER Georges, 2008, « Le cerveau, simulateur dans tous ses états », *Revue philosophique*, 133/3, p. 347-354.

CHAPOUTHIER Georges, 2009a, « Mosaic structures, a working hypothesis for the complexity of living organisms », *E-Logos* (*Electronic Journal for Philosophy*), 17 [Online: http://nb.vse.cz/kfil/elogos/biocosmology/chapouthier09.pdf].

CHAPOUTHIER Georges, 2009b, *Kant et le chimpanzé – Essai sur l'être humain, la morale et l'art*, Paris, Belin, coll. « Pour la Science ».

CHAPOUTHIER Georges, 2011 [1999], « La mémoire en mosaïque », *in* Jean-François DORTIER (ed.), *Le Cerveau et la pensée, le nouvel âge des sciences cognitives*, Auxerre, Éditions Sciences Humaines, p. 222-226.

CHAPOUTHIER Georges, 2013, « Des parcours littéraires en mosaïques », Revue indépendante, 338, p. 18-21 [Online: https://halshs.archives-ouvertes.fr/halshs-00848783/file/Chapouthier_Parcours_littA_raires_Paru_dans_Revue_IndA_pendante_2013_NA_338_pp_18-21.pdf]

CHAPOUTHIER Georges & Frédéric KAPLAN , 2011, *L'Homme, l'animal et la machine : perpétuelles redéfinitions*, Paris, CNRS Éditions, p. 17-18.

CHAPOUTHIER Georges & Alain POLICAR, 2015, « La néoténie humaine, une idée à relancer », *Pour la Science*, 452, p. 14-15.

CHERLONNEIX Laurent, 2008, *L'Équivocité vive : une nouvelle représentation du vivant*, Paris, L'Harmattan.

DELACOUR Jean, 2001, *Conscience et cerveau, la nouvelle frontière des neurosciences*, Bruxelles, De Boeck.

DE WAAL Frans, 1989, *Peace Making among Primates*, Cambridge, Harvard University Press.

DE WAAL Frans, 2006, *Our Inner Ape: the best and worst of human nature*, London, Granta Books.

FELDENKRAIS Moshe, 1994, *Body Awareness as Healing Therapy: the case of Nora*, New York, North Atlantic Books.

FRIEDENKRAFT Georges (ed.), 1993, « Poèmes brefs, poème long », *Jointure*, 38, p. 15-39.

GIVÓN Talmy, 1998, « The functional approach to grammar », *in* Michael TOMASELLO (ed.), *The New Psychology of Language*, London, Erlbaum.

GOULD Stephen Jay, 2002, *The Structure of Evolutionary Theory*, Cambridge, Harvard University Press.

GUJA Cornelia, 2008, « Biocosmology and informational anthropology: some common aspects », *E-Logos* (*Electronic Journal for Philosophy*), vol. 15 [Online: http://nb.vse.cz/kfil/elogos/biocosmology/guja08.pdf]

HAMMERSCHMIDT Katrin, ROSE Caroline J., KERR Benjamin & Paul B. RAINEY, 2014, « Life cycles, fitness decoupling and the evolution of multicellularity », *Nature*, 515, p. 75-79.

HASHI Hisaki, 2011, « Mechanism versus organism », *in* Friedrich G. WALLNER & Hisaki HASHI (eds), *Globalisierung des Denkens in Ost und West*, Nordhausen, Verlag Traugott Bautz GmbH, p. 105-115.

HEISER Marshall, 2012, « SMiLE: Brian Wilson's musical mosaic », *Journal on the Art of Record Production*, 7

[online: http://arpjournal.com/smile-brian-wilson%E2%80%99s-musical-mosaic/].

HOMBERT Jean-Marie & Gerard LENCLUD, 2014, *Comment le langage est venu à l'Homme ?*, Paris, Fayard.

IGLÓI Kinga, DOELLER Christian F., BERTHOZ Alain, RONDI-REIG Laure & Neil BURGESS, 2010, « Lateralized human hippocampal activity predicts navigation based on sequence or place memory », PNAS, 107/32, p. 14466-14471 [Online: http://www.affective-sciences.org/system/files/biblio/PNAS-2010-Igl%C3%B3i-14466-71.pdf].

IMANISHI Kinji, 2002, *A Japanese View of Nature: the world of living things*, London, Routledge.

JONAS Hans, 2001, *The Phenomenon of Life: toward a philosophical biology*, Noyes S^{t}. Evanston, Northwestern University Press.

KHROUTSKI Konstantin S., 2008, « Biocosmology – rehabilitating aristotle's realistic organicism and recommencing Russian universal cosmism: response to Arthur Saniotis », *Eubios Journal of Asian and International Bioethics*, 18, p. 98-105.

KHROUTSKI Konstantin S., 2010, « All-embracing (triune) medicine of the individual health: a biocosmological perspective », *Journal of Future Studies*, 14/4, p. 65-84.

KHROUTSKI Konstantin S., 2013, « Forming an evolutionary vector to the Aristotelian pole of scientific organicism (Biocosmology) », *Biocosmology-Neo-Aristotelism*, 3/1, p. 28-51 [Online].

KOVÀC Ladislav, 2015, *Closing Human Evolution: life in the ultimate age*, Heidelberg, Springer Verlag.

KREUTZER Michel & Verena AEBISCHER, 2015, « The Riddle of Attractiveness: looking for an "Aesthetic Sense" within the hedonic mind of the beholders », *in* Thierry HOQUET (ed.), *Current Perspective in Sexual Selection*, Heidelberg, Springer Verlag, p. 263-285 [Online: http://lecd.u-paris10.fr/medias/fichier/6-kreutzer-aebischer-the-riddle-of-attractiveness_1445972880729-pdf].

LAMING Denis, 2015, « La ville », *in* Jean AUDOUZE, Georges CHAPOUTHIER, Denis LAMING & Pierre-Yves OUDEYER, *Mondes mosaïques*, Paris, CNRS Éditions, p. 59.

LANGANEY André, 1991, *Le Sauvage central*, Paris, Éditions Raymond Chabaud.

LEGUAY-TOLLERON Catherine, DANEL Françoise, LANGLET Dominique & Isabel ASÚNSOLO, 2013, *Le Rayon du bas*, Beauvais, Éditions L'Iroli.

LESTEL Dominique, 2001, *Les Origines animales de la culture*, Paris, Flammarion.

LIBBY Eric & Paul B. RAINEY, 2013, « A conceptual framework for the evolutionary origins of multicellularity », *Physical Biology*, 10 [Online: http://iopscience.iop.org/article/10.1088/1478-3975/10/3/035001/pdf].

LUPASCO Stéphane, 1951, *Le Principe d'antagonisme et la logique de l'énergie. Prolégomènes à une science de la contradiction*, Paris, Éditions Hermann & Co.

MATRAS Jean-Jacques & Georges CHAPOUTHIER, 1984, « La néguentropie : un artefact », *Fundamenta Scientiae*, 5/2, p. 141-151.

MICHOD Richard E., 1999, *Darwinian Dynamics: evolutionary transitions in fitness and individuality*, Princeton, Princeton University Press.

MICHOD Richard E., 2009, « Socialité et sexe : coopération et conflit, des molécules aux sociétés », *in* Alexandrine CIVARD-RACINAIS & Pierre-Henri GOUYON (eds), *Aux Origines du sexe*, Paris, Fayard.

MODELL Stephen M., 2006, « The two arrows of efficiency: a commentary on Konstantin S. Khroutski's BioCosmology – Science of the universal future », *E-Logos* (*Electronic Journal for Philosophy*), vol. 13

[Online: http://nb.vse.cz/kfil/elogos/biocosmology/modell06.pdf].

MODELL Stephen M., 2011, « Taking biological form to the next level: synthesis as a dimensional process in the biocosmology of life », *Biocosmology-Neo-Aristotelism*, 1/2-3, p. 274-292 [Online].

MORRIS Desmond, 1967, *The Naked Ape*, London, Jonathan Cape.

NUROCK Vanessa, 2011, *Sommes-nous naturellement moraux ?*, Paris, Presses universitaires de France.

NUROCK Vanessa, 2012, « Pourquoi la philosophie morale devrait-elle s'intéresser à l'éthique animale ? », *in* Florence BURGAT & Vanessa NUROCK (eds), *Éthique et philosophie de l'environnement*, Paris, Éditions Wildproject.

OHNO Susumu, 1970, *Evolution by Gene Duplication*, Munich, Springer Verlag.

OUDEYER Pierre-Yves, « Quand les machines créent leur propre complexité », *in* Jean AUDOUZE, Georges CHAPOUTHIER, Denis LAMING & Pierre-Yves OUDEYER (eds), *Mondes mosaïques*, Paris, CNRS Éditions, p. 206-207.

PELLUCHON Corine, 2011, *Éléments pour une éthique de la vulnérabilité – Les Hommes, les animaux, la nature*, Paris, Le Cerf.

POULAIN Bernard, 2010, « Botulinum neurotoxin », *Revue de Neurologie*, 166/1, p. 7-20.

PRIGOGINE Ilya & Dilip KONDEPUDI, 1998, *Modern Thermodynamics: from heat engines to dissipative structures*, Chichester/New York, John Wiley.

ROBERT Stéphane & Georges CHAPOUTHIER, 2013, « The mosaic of language », *in* Béatrice FRACCHIOLLA (ed.), *Les Origines du langage et des langues*, Paris, L'Harmattan, p. 211-223.

RUYER Raymond, 1968, *La Cybernétique et l'origine de l'information*, Paris, Flammarion.

SANIOTIS Arthur, 2013, « Evolutionary complexity in relation to Georges Chapouthier's mosaic biological structures », *Biocosmology-Neo-Aristotelism*, 3/2, p. 334-340.

SATO Hiroaki, 1983, *One Hundred Frogs, from renga to haiku to English*, New York, Weatherhill.

SCHACTER Daniel L., 2001, *The Seven Sins of Memory: how the mind forgets and remembers*, Boston, Houghton Mifflin publishers.

SCHAEFFER Christophe, 2012, *Le Rugby expliqué à mon fils ou l'art de rester lié*, Paris, L'Harmattan.

SHIRANE Haruo, 2012, *Traditional Japanese Literature: an anthology, beginnings to 1600*, New-York, Columbia University Press.

SIMONDON Gilbert, 2008, *Imagination et invention*, Paris, Éditions de la Transparence, p. 148/163-164.

SMAJS Josef, 2008, *Evolutionary Ontology*, Amsterdam, Rodopi publishers.

SOROKIN Pitirim A., 1965, « Sociology of yesterday, today and tomorrow », *American sociological Review*, 30/6, p. 833-843.

TASIC Milan, 2013, « Philosophy of mathematics: naturalism *vs*. category theory », *Philosophy Study*, 3/10, p. 929-944.

TINLAND Frank, 1977, *La Différence anthropologique : essai sur les rapports de la nature et de l'artifice*, Paris, Éditions Aubier-Montaigne.

TONNELAT Jacques, 1995, « L'ordre issu du hasard », *Comptes-Rendus de la Société de Biologie*, 189, p. 215-237.

TONNELIER Arnaud, MEIGNEN Sylvain, BOSCH Holger & Jacques DEMONGEOT, 1999, « Synchronization and desynchronization of neural oscillators: comparison of two models », *Neural Networks*, 12, p. 1213-1228.

UGOLEV Aleksandr M. & V.T. IVASHKIN, 1992, « Theory of universal functional blocks and fundamental biomedical problems », *Klinical Medecine*, 70/2, p. 8-14.

VENAULT Patrice & Georges CHAPOUTHIER, 2007, « From the behavioral pharmacology of beta-carbolines to seizures, anxiety and memory », *The Scientific World Journal*, 7, p. 204-223.

VON BERTALANFFY Karl Ludwig, 1968, *General System Theory: foundations, development, applications*, New York, George Braziller.

WANG William S.Y., 2007, « The language mosaic and its biological bases », *Journal of Bio-Education*, 2/1, p. 8-16.

YAMAWAKI Naoshi, 2009, « Pour une philosophie publique et transnationale », *Diogène*, 227, p. 182-202.