

## Chapter 2

# Ontic Openness as Key Factor in the Evolution of Biological Systems

Søren Nors Nielsen and Claus Emmeche

**Abstract** The heterogenic character of biological systems has as a consequence that calculations of their possible combinatorial constellations very soon run into numerical explosions. This means, that the resulting numbers—so-called immense numbers—exhibit orders of magnitude beyond any physical meaning. Such a high number of possibilities cause another property—named ontic openness by the physicist W. M. Elsasser—to emerge within such systems. All biological systems possess the feature of being ontic open and this is of great importance to evolution, as ontic openness not only guarantees a development of the system to take place, but also interferes with our chances to fully comprehend this evolutionary processes *sensu lato*. Thus ontic openness implies an extremely high level of uncertainty and unpredictability. On the one hand, we have a certainty that “something” is bound to happen within the system—on the other hand, we can be totally sure that we will never be able to forecast exactly whatever that “something” will be. At lower levels of biological hierarchy, e.g., the molecular level represented by molecules like DNA, RNA, and proteins, ontic openness seems pretty easy to comprehend. When it comes to more aggregate and even conglomerate systems, i.e., at higher levels of biological hierarchy, the emergence as well as the expression of this property becomes increasingly obscure. Although definitely present, the property at superior levels tends to be overlooked or neglected. Although the calculations may take different forms—and in spite of finding different causes—the property penetrates through all levels of biological hierarchy. To prevent systems from ending up in a situation where the evolutionary state described by calculations that are incomprehensible or even intractable constraints

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S. N. Nielsen (✉)

Department of Learning and Philosophy, Aalborg University, Copenhagen,  
A.C. Meyers Vænge 15, 2450 Copenhagen SV, Denmark  
e-mail: soerenhorsnielsen@gmail.com

C. Emmeche

Center for the Philosophy of Nature and Science Studies, University of Copenhagen,  
Copenhagen, Denmark  
e-mail: cemmeche@ind.ku.dk

of the systems are needed. From the different levels some systematic patterns seem to be recognizable. Whereas lower levels find causes inside–upwards to be dominating, at upper levels causes become dominated by outside–inwards interactions. Eventually, the ontic openness is likely to be limited not only by physical dimensions but is also constrained by downward acting factors. One reason for this is that space and time scales are well-known to be tightly coupled throughout the biological hierarchy—smaller scales have fast reaction rates as opposed to large scale with slower functions. Thus, space and time scales become important to the realization of ontic openness. At the same time, a shift occurs that stresses information exchange and treatment together with cognitive processes to be increasingly dominant in the biosemiotics of the ongoing processes. The whole leads to a shift from dominance of objective factors to more subjective ones in the process of evolution. Viewing evolutionary systems as ontic openness systems and pursuing the constraints influencing them may turn out to be a fruitful strategy to the investigation of all developmental processes.

## 2.1 Introduction

Most researchers in areas of science, such as physics, chemistry, and biology have most likely during their career given thoughts to the remarkable property we call “life” as opposed to the much more inert system we also deal with within the natural sciences for instance in physics. What exactly makes the two types of systems differ? Many words have through time been used to designate what are the essential properties that define life or life processes, among others, possibility to replicate, storage and treatment of information, self-similarity, self-organization, network properties, etc.

At the same time, probably not many have done any considerations about the real “uniqueness” of living systems (Ulanowicz 2009). The state of this uniqueness is among others a derivative of the works of and considerations done by the physicist Walter M. Elsasser (1904–1991, 1998). Although being trained in the area of nuclear and quantum physics, Elsasser’s career forced him into activities of many other only remotely related disciplines in areas such as meteorology, and in particular earth sciences. He is probably best known for his contributions concerning Earth’s magnetism, where it was his findings that eventually lead to the discovery of plate tectonics. For further information we refer to a recently published biography (Rubin 2005).

Less known is probably a quite large part of his production inspired among others by Niels Bohr in which he dealt with considerations on the actual difference between living and physical systems. In a series of papers (Elsasser 1963, 1964, 1969a, b, 1972, 1981a, b, 1982, 1983) and four books (Elsasser 1958, 1966, 1975, 1998) he developed a synoptic framework with a more or less specific nomenclature to describe his views and predominantly phenomenological observations

concerning the characterization of physical versus biological systems. For a brief, yet more detailed introduction see later. All in all, his findings have a great potential impact on the way we understand evolutionary biology.

In general, evolutionary (neo-) Darwinian theory includes four aspects that form the core idioms of the theory, (as for instance stated and presented in Christiansen and Fenchel 2009) namely (1) an excessive production of offspring, (2) that the individuals produced are different and that this difference is heritable, (3) that the most fitted species have the highest probability to survive and reproduce, i.e., will be *selected* for. The previous points will (4) lead to a change between generations and that the species will be adapted to meet environmental changes (modified from Christiansen and Fenchel 2009).

Out of all this, the *principle of selection* (points #3 and #4 above) has received major attention and the discussions in this area have led to many treatments abundant in the scientific literature. Beyond no doubts, this is for several reasons, such as the weaknesses in the definition of “who” is carrying out this selection, or exactly “what” causes it to come by? What is it exactly that is selected for? And if fitness, then how is this fitness defined? Debates in this area have not ended and are not likely to be settled for years, although some indications exist (see Jørgensen et al. 2007) that fitness is most likely to be best understood as some sort of optimal energetic relation with the surroundings or even optimum thermodynamic efficiency (Jørgensen 2002).

As opposed to selection the necessary *principle of variation* that according to #2 above lies beneath the whole has received much less attention at least when it comes to the way it is considered here. The principle of variation is included in the “differences” among the excessively produced number of individuals, but so far close to nothing is stated about how these differences emerge nor has an underlying principle such as ontic openness been described.

Obviously, the genetics of mutations and the discovery of the genomic structure were necessary to build a platform for understanding the variation properly. In brief, having gained this insight variation seems to be what comes by when chromosomes undergo point and other mutations, and when genes becomes shuffled around during the mitotic and meiotic processes at lower levels of hierarchy and when individuals exhibit sexual reproduction are involved (see later). All in all, a plausible and sufficient explanation to variation at this level of hierarchy, but it leaves a picture that is far from complete. Although for instance, Mendelian laws allow for prediction to be made about the frequencies of certain characteristics within a given species, the calculations are still deterministic in the sense that for instance frequencies of alleles predicted from these laws are fixed.

Attempts of modeling gene distributions and fitness landscapes using stochastic methods often leads to distributions dominated by “noise”, which is disturbing to both conclusions and computing time. The problem about such models is probably a lack of constraints that lead to too many degrees of freedom and an unrealistically high variability. What one would expect to see is rather a decrease in variability and noise as an effect of the system being constrained. A conjecture can be proposed that this would be expressed in a corresponding decrease in an entropy

like expression (or any isomorphic forms of equations) when calculated and observed from the system development over time.

It is possible that the sufficiency of such an explanation have had the consequence to draw the attention of the evolutionary science away from a more obscure and profound “variation principle” that lies inherent in all such systems. Such a principle is nevertheless the direct outcome of the considerations done by Elsasser in his theoretical works. The difference in view is now that the variation we pursue and investigate here is about anything else but deterministic (see earlier comment above).

Another reason seem to be that the philosophical works of Elsasser have only recently begun to get some attention. In spite of the fact that the philosophical issues are not too difficult to grasp, we are left with the fact that the messages brought to us some times may seem overwhelming. In fact, many physicists are reluctant to discuss the issues emerging from Elsasser theories for the reason that his calculations reach numbers that according to them are beyond physically any meaning. Meanwhile, such numbers belong to the everyday life of not only biological researchers, and mathematics allows us to calculate them. Therefore, we should not ignore the message they bring.

We can at this point no longer avoid mentioning that the key property of biological system by Elsasser is termed *ontic openness*. All systems which are sufficiently *heterogenic*,—which may be roughly explained as being composed of a large variety of distinguishable elements with difference properties,—will possess this property. Such systems are said to be *ontic open*. Ontic openness in short expands the system by giving it some extraordinary high degrees of freedom, at a level much higher than we used to think of. The “extra” degrees of freedom provide such a system with an intrinsic property that on the one hand ensures evolutionary powers of the system as evolution in this context has no limits. On the other hand, it can be concluded that evolution therefore must be met with limits of some kind, i.e. needs to be constrained. Variation and ontic openness must be viewed together with selection and constraints.

While an earlier contribution (Nielsen and Ulanowicz 2011) has advocated ontic openness as an essential feature at lower levels of biological hierarchy and of ecosystems, this paper argues that the property penetrates to all intermediate levels and examines the various ways that ontic openness emerges. In this context, the concept of code duality (digital and analog codes) introduced in biosemiotics by Hoffmeyer and Emmeche (1991) may be used in order to understand the importance of processes behind ontic openness and eventually shaping its outcome by constraints. Moving up the hierarchy, the binary code dependency still exists but is of reduced importance, whereas the analog codes become increasingly dominant. Thus, a totally randomized outcome of the ontic openness may be objectively and physically constrained at lower levels. The higher the level in the biological hierarchy the more a subjective layer of ontic openness is added to the semiotic processes. The constraints at the same time become involved and dominate these activities, although the system still has to obey physical constraints (Nielsen 2009).

## 2.2 Elsasser and Ontic Openness

The basic distinction between physical and biological systems introduced by Elsasser was that the first type of ensembles (sets) could be characterized as *homogeneous*, whereas the latter type were dominated by a high degree of *heterogeneity*. It is a well-known fact that many physical systems may be described as assemblies of elements or particles that all share approximately the same properties or to use Elsasser's formulation they are homogeneous. It is this homogeneity which makes it possible for us to describe and predict their collective behavior from statistical (mechanical) considerations.

The possibility to treat higher level, conglomerate systems by such average considerations is impossible, simply because their behavior and properties of the elements come to deviate too much from one another. Adding up to this comes also the fact that being conglomerate indicates that they may appear in quite different constellations leading to variations also in quantitative and qualitative properties. Theory of sets may assist in developing an increased understanding in this area.

Heterogeneity is a prerequisite for the possibility to bring around variation in constellations, just as it is the 4–5 nucleic acids making up strings of RNA and DNA that may vary in time and space,—the simplest spatial view being the two-dimensional one presented here. The variability is not restricted to being one–two-dimensional as it is clearly demonstrated already by the proteins and enzymes.

The central issue here is now that heterogeneity introduces a vast number of possibilities that may never be reached neither in time nor space, i.e., evolutionary possibilities that will never be realized (Nielsen and Ulanowicz 2011). This is for two reasons which are fundamental, though few biologists have giving them any thoughts. First, evolution did not have that much time actually to realize all possibilities. In fact, often the argument has been heard, that if only evolution had time enough, this or that feature would be developed. The second argument is striking in all its simplicity. The universe does not have particles enough to allow evolution to construct all possibilities, not to say allow them to be evaluated against each other at the same time. Thus, it is an imperative that a major part of the evolutionary space is void.

Elsasser's argument around his concept of ontic openness is in fact based on some quite simple considerations. Given the time of existence of universe ( $14 \times 10^9$  y)—and its number of participating elements ( $10^{83}$ )—and the fastest rate with which events in the system (our universe) could happen (one event per  $10^{-9}$  s)—a total of all possible number of events or constellations of the participating elements (elementary particles) that could have been realized can be calculated. This reaches a number in the order of  $4.4 \times 10^{109}$ .

Elsasser introduces a level where any number of more than  $10^{100}$  (a number referred as Googol) is referred to as *immense*. Systems where combinatorial considerations on possible number of constellations lead to numbers higher than Googol are said to be *ontic open* or possess *ontic openness*. The property is an intrinsic feature existing in all heterogeneous systems and leaves us with an

overwhelming number of possible realizations of such systems. Each constellation realized has no identical twin and is fully unique.

The numbers are conceived of as being beyond any physical meaning, hence the resistance among physicists to discuss them, and yet they can be calculated as objective possibilities. In fact reaching such high numbers, described as inconceivable is quite easy in biology. In the world of biologists in general, e.g., genetics, evolutionary biology, physiology, and ecology, such numbers are often reached when attempting to describe possible constellations. Rather than refusing to discuss such numbers, it seems more obvious to face the problem and try to interpret what they mean to the problem we attempt to analyze.

As said, to reach immense numbers during calculations of possible constellations of a biological system is quite easy only the background on which it is calculated differ depending on the ontological consideration. We therefore need to define the level of ontology at which the property of ontic openness emerges. In fact, referring to everyday life we face many situations where ontic openness manifests itself outside a strictly biological context, in the books we read, in the music we hear, in the environment we perceive, and may conclusively only perceive part of. Meanwhile, perception really belongs to the discipline of studying communication among organisms in its widest sense and may therefore be seen as included in biology domain too (as Bateson, Uexküll, and other theoretical biologists have been aware of).

What really stands out when trying to comprehend this inconceivable fact is that the existing life forms seem to have emerged by choosing among the members and realizing sets from an “urn” covering an unfathomable number of possibilities, numbers that seem to be even beyond the infinite. Ontic openness prevails and really seems to be the rule rather than the exception.

When trying to condense some statements relevant to evolutionary biology out of the above characteristics describing the calculations on ontic open system, the following issues seem to be more important.

In an ontic open system, unexpected things are bound to happen and in fact repetition of events is unlikely, or, to take the full consequence, impossible. What has happened once will never occur again. Something similar maybe,—but never exactly the same. For an illustrative example of the (im-)possibility of catching a given number of persons in exactly the same place after a year please refer to Ulanowicz (2009).

This brings the message to us that not only are all states of ontic open systems unique, they are also totally unpredictable. At the same time as we have a “guarantee” that something will happen in them, we can be sure that we will not be able to predict exactly what will happen, and we can be sure that once something has happened precisely the same thing will **never** happen again.

The question immediately raises how to bring in such considerations into not to say understand an evolutionary biology context. What are the extras needed in order to bring us to understand the evolutionary mechanism better? How do we understand the relatively stable evolutionary picture we observe from a situation which forecast such a high level of indeterminacy and uncertainty?

## 2.3 Ontic Openness and Evolutionary Phase Space(s)

It is implicitly clear that such views carry some unpleasant, but also, important messages not only to evolutionary ecology but to all parts of biology that involves ontic open systems.

In fact, ontic openness has the consequence that not only species are unique but so are also the individuals within a population of each of the many species that make up the diversity of the world. As pointed out by Williams (1998, 1st ed. 1956), investigating the physiology of humans, we share no absolute similarity to any other humans, except from ourselves. Even identical twins are not totally identical in this context.

Yet we consider all 7.5 billions of persons on Earth as belonging to the species of *Homo sapiens* and we will immediately recognize a member even if we are definitely not identical even if we do share our looks and are at least superficially similar.

In order to perceive this, species are not any longer small twigs or branches of an evolutionary tree as it may appear from a macroscopic point of view. When zooming in, we will identify the evolutionary lines of species as bundles of individuals each with their own unique history.

Ontic open systems are provided with an intrinsic “mechanism” of development or evolution. Every time it is possible to take new avenues they are seen available and will be taken.

Furthermore, this type of development in itself does not take any direction but our interpretation, depending on a chosen frame of reference specifying a specific fitness landscape, will allow us to describe a given step as being in a progressive direction (i.e., leading to more adapted, better fitted organisms), or if we will describe it as regressive (leading to a less adapted, lower fitness organism), or if the inevitable variation will introduce any change at all.

At the same time, it is worth to notice that ontic openness of the genome (1) allows for and explains the existence of punctuated equilibria (*sensu* Eldredge and Gould 1972; Gould 1989), and (2) also implicitly determines that part of the evolutionary phase space must be void and only parts of the phase space close to the presently realized are valid solutions, that is only the “adjacent” is “possible” (Kauffman 1995, 2000).

## 2.4 Ontic Openness and Levels of Hierarchy

If it is really the distinction between systems being either homogeneous or heterogeneous that makes ontic openness possible and if taking the stance that ontic openness has importance in evolution, it seems fair to ask the question when exactly do the systems and components get complex enough, i.e., get sufficiently heterogeneous as seen through the eyes of evolutionary biologists, to talk about

genuine heterogeneity, and thus biological evolvability. Complexity is here used in its widest sense and may be a result of variety in compositional elements and their interrelations both as physical flows or any type of regulatory interactions.

Unfortunately, the answer is not an easy one although a sketch can be drawn. Clearly, to have a world composed of simple and relatively inert inorganic molecules is not enough. We may today find a number of this type of compounds in the order of magnitude of some hundreds (less than 700) atomic(/molecular?) subcomponents under natural conditions. A typical example of homogeneous systems are crystalline structures. Under pre-biotic conditions, the number must have been considerably lower as oxygen was not available. We know, from the experiments of Miller and Urey (Miller 1953; Miller and Urey 1959) that the presence of simple organic molecules of various kinds is possible when a (closed) system is exposed to inputs of energy. All in all, this would result in systems where building blocks were ready but still without ontic openness.

Several setups may have facilitated in the production of essential molecules, localized structures with simple cycles facilitating transports and thereby chemical conversions, such as Turing structures, Benard—Cells, Beluzov—Zhabotinsky reaction like (oscillating spatial) patterns and hypercycling (Eigen and Schuster 1979). At a later state the systems became thermodynamic open, encapsulated in micelles formed by bipolar compounds spontaneously produced and allowing free movement of energy and matter over the boundaries. In addition, the fact that carbon is the core element of life brings about heterogeneity to the living world. Not-surprisingly, the number of organic molecules exceeds 10 millions.

The giant leap must have occurred at a time when some of the molecules joined each other to form longer and longer chains making variable combinations possible. Ontic openness was possible from the time where proteins, RNA and DNA had been formed. Most of these molecules of these types demonstrate even in the simplest forms we know today the property of ontic openness. This is based on a one-dimensional perception (linear organization form) only and not considering other secondary, tertiary, or quaternary configurations.

### ***2.4.1 Macromolecules***

At this level, the property of ontic openness stems from the various possibilities of putting together the hereditary material, its storages, messengers, and products, such as enzymes. We find this property among all the macromolecules inside the systems. This has several consequences for a system to possess an ever qualitatively changing material. First of all, because ontic openness has the consequence that replication can never be carried out precisely, that is, without the introduction of deviations from the original. These errors are the source of all evolution, development, and aging. Second, even if proofreading is carried out even this process will not be without mistakes either. The response of the system will be a result depending on the functional changes introduced to the system. The effect of



the changes may be improvements, degrading, or even potentially lethal (see also the above). At this time, it should be noted that redundancy of the genetic material (in addition to proofreading) could be seen as ways to compensate for the ontic openness of the genome. Also it is known that codons that may be replaced without inducing any qualitative changes at, for instance, enzymatic activity is placed on the outside, whereas essential codons are wrapped up and protected by the tertiary structure.

### **2.4.2 Cells**

At the cellular level, i.e., cells including organelles, all functions come by as a response to several types of molecules and the specific functions now connected to the various organelles, like in the nucleus, endoplasmic reticulum, Golgi-apparatus, mitochondria, etc. The organization retains its ontic openness if for nothing else due to its close connection to the macromolecular level.

Second, the compartmentalization can be seen as making the system even more open since the division of processes allows for even more variations to occur and for instance the possibility of even larger deviation from thermodynamic equilibrium (Nielsen 2000). A sufficiently large collection of (individual) cells (as opposed to the organs in the following) will likewise be ontic open.

### **2.4.3 Organs**

A major consequence of collecting cells with similar function in the larger constructs is apparently a reduction in ontic openness. Ontic openness becomes reduced already during differentiation and determination and the fact that the cells have similar functions points in the direction of homogeneity. Other processes like communication between the organ's cells seem to enhance the uniform action of the cells. Whereas ontic openness if for sure retained among the genetic mechanisms being expressed in the main processes of the organs it seems heavily controlled. The function of organs may well be the first level where ontic openness is really reduced by constraints from higher levels. This type of communication should be included in considerations on the next level.

Meanwhile, dedicating certain cells to specific functions indirectly has the consequence that more types of cells must emerge and not even particular organ types have only one type of cells. The ontic openness is shifted to the combinatorial possibilities that exist between all cell types.

### 2.4.4 *Individuals*

Individuals are systems composed of cells containing genomes and organelles, put together in organs, endo- or exo-skeletons and an encapsulating membrane, in the case of humans—our skin. Such a basic view holds throughout the plant and animal kingdoms. As the hierarchical levels embedded in the organisms are all ontic open it implies that systems when viewed at the level of individuals are also ontic open. Meanwhile, the findings of Williams (1998) indicating that we are only identical to ourselves may appear as overwhelming. In medicine and pharmaceutical sciences, new strategies have been set up to search for “individual medicine”. If this is taken too literally, the fact that the physiology of the human organism is ontic open may well force this paradigm into a crisis and sequentially to be reformulated. The best we can hope for is treatment of sets and maybe this would lead to a better research strategy.

The level of individuals when covering the whole evolutionary tree does span over quite a big range of organizational forms and functionalities, from mono-cellular to multicellular organisms, from autotrophs to heterotrophs. Ontic openness is inherent in all the organisms if for nothing else due to the complexity of the genome. But the constraints seem to change. The difference seems to be best understood in terms of changes in the way that communication takes place in the system. For this purpose, the code-duality perspective on the semiotic processes in biology as introduced by Hoffmeyer and Emmeche (1991) is convenient.

In brief, all exchange of information and communication within or among biological systems may be understood within the framework of biosemiotics, a recent scientific field based in part of the works of Jakob von Uexküll (1926). According to Hoffmeyer and Emmeche, this informational process can be seen as either digital or analog in character where the digital, binary ways of communication can be related the molecular level (especially DNA as a digital memory), whereas most of the other exchanges of information are taking form of analog processes. In multicellular organisms with perception and action cycles, there is a continuous exchange of information between organism and environment, and this “sign action” helps the organism to adapt to the physical environment by representing and processing significant cues of the environment (the creation of an inner Umwelt) upon which actions are based.

When viewed in this manner a general trend can be observed. Focusing at the lower and inner levels of the biological hierarchy ontic openness is a consequence of fluctuations in the digital coding systems. When moving upwards in the hierarchy these “inner” fluctuations still exist but become constrained and leveled out by other communicative processes that are analog in character.

A separate ontic openness is expressed through the internal relations of the individuals. Any interaction between individuals is considered to belong to the population level.

### **2.4.5 Population**

Individuals belonging to the same species that are in themselves ontic open come together in larger collections usually referred to as a population. The exchange between the genomes of individuals as it happens for instance in connection to sexual reproduction only serves to an increase in ontic openness. This is probably not the right way of formulating it since either a system is ontic open or it is not. Rather, we should in this situation describe the process of sexual reproduction as adding an extra layer that is also ontic open. This is a detail that only affects the way we would calculate the number of combinatorial possibilities and has no effect to the conclusions made for the systems.

The shift in code duality now becomes more apparent when we talk about populations as societies where members of a species exhibits some sort of cooperation such as it can be observed in bees and ants. Communication certainly becomes an important factor that serves to shape the outcome of the events going on between members within such groups of species.

It is also clear from population ecology that it takes populations to be over a certain “viable” size to persist. In other words, they are to be kept ontic open. What we have done when we as humans interfere with the distribution of various other species in our environment is in fact that we most often decrease (bio-) diversity, that is, reducing the ontic openness of the systems. When talking about endangered or extinct species, we are referring to a reduction in ontic openness to a level where the populations’ size is not viable any longer.

### **2.4.6 Communities**

The introduction of this concept introduces an ontic openness that is strongly correlated with landscapes and the spatial variational component in the distribution of species. As remarked by Allen and Hoekstra communities are composed of individuals belonging to a number of species are therefore to be considered complex (Allen and Hoekstra 1992). The composition alone makes the communities ontic open.

Communities of organisms are mostly seen as belonging to the same (trophic) group of individuals and that communities have both a vegetational and a zoological side to it, which is often neglected. On the one hand, adding such a perspective seems to add up to the ontic openness. Meanwhile, the increase might not be correlated to a simple combinatorial calculation but it is more likely that many parallel communities exist, that may look similar but where certain species of plants rely on particular animal and vice versa for their existence.

### 2.4.7 *Ecosystems*

Ecosystems are of course ontic open too (Jørgensen et al. 2007). In general, as pointed out by Ulanowicz, it takes no more for a system than to be composed of around 75 distinguishable components (or tokens) for it to be ontic open (Ulanowicz 2006). It is quite a task to analyze and fully understand an ecosystem. In fact, it can be shown to be physically impossible (Jørgensen et al. 2007). Not surprisingly, this requirement of the necessary complexity is easily fulfilled by ecosystems. Considering that most ecosystems easily demonstrate a composition with a number of members in this order of magnitude, and to this we should consider to add also variety in flows and in chemical species, as well as include all regulatory (cybernetic) mechanisms, then the need for complexity in terms of state variables is probably even lower.

It seems not to be necessary for this purpose to argue that ontic openness also penetrates to levels of hierarchy like landscapes, regions, and even the biosphere. The greatest difficulty when looking upon this in a higher level context is the fact that the ontic openness of other processes, for instance, influences from the human society comes to act as noise to the system (Nielsen and Müller 2009). Issues concerning these levels are therefore omitted from this treatment.

## 2.5 Subconclusion

Ontic openness is a reality at all levels of biological hierarchy. Even if the way it can be calculated depends on the ontology imposed on the system this is not considered to have any effect on the conclusions about the evolutionary potentials of such a system. The types of hierarchy varies from being embedded (2.4.1–2.4.4 above) to be of a scalar type of hierarchy (2.4.4–2.4.7 above). By “embeddedness” here it is meant that the sub-systems are successively included within the series of physical boundaries. The ontic openness of the upper levels includes the ontic openness of lower layers but adds extra dimensions to it. Each organizational layer seems to possess an additional layer type of ontic openness of its own based on an analog type of semiotic information exchange. The upper level ontic openness acts to constrain the lower levels.

## 2.6 Discussion

As it is clear from the introduction, all possible constellations of an ontic open system cannot be realized as the universe (1) neither have components enough, (2) nor does it or will exist long enough. Two severe limitations imposed on biological systems of which the prior seems quite the strongest. In other words, parts of the evolutionary phase space has to be left void.

As we have seen ontic openness in itself has no values to it. What exactly comes of possessing this feature may be difficult to say. It is simply a basic feature of our universe, and although it highlights some important aspects of its evolution, we can only imagine very artificial and highly idealized universes lacking this feature (e.g., simple mathematical models of evolution). What we can say is that it seems valid for an evolutionary line to exist at some new points that may possibly be taken up by a further realization of ontic openness that, although they are totally random, still fulfill the rules of the game. “Totally random” here does not mean instantly created from scratch or by design, but based upon a long process of already evolved structures, and thus being contingent relative to the pre-history of the system in question, but not pre-determined regarding its further evolution (cf. Gould 1989).

The fact that the ontic openness of the upper levels includes the ontic openness of lower layers points to the fact that all upper layers have an inside–outside, inward–upward component to their ontic openness (a parallel view to the findings in Nielsen 2009).

Considering evolutionary time and space scales at large it seems that the random component of ontic openness must have been most active and important during the early evolutionary states. Very early in the emergence and invention of new functional principles, cf. photosynthesis the evolutionary phase space is struck by a lock-in situation, where certain demands are to be fulfilled and other solutions are not valid any longer. The importance to later states is probably reduced to ensure the variational principle but the degrees of freedom with which ontic openness can be realized is heavily constrained.

Another point is that time and space scales are correlated. Normally, systems with small space scales of the live and react on short time scales, whereas larger systems possess longer time scales.

It would be tempting to relate this observation with the changes in the dominant part of the code duality. The digital code forms seem to have the necessary time of reacting, whereas the analog coding seems more suitable at higher levels. Meanwhile, to reach such a conclusion seems not to be valid as many digital and analog coded processes react on approximately the same time scale. The statements around this are illustrated in Table 2.1.

Rather it seems that different types of semiosis could be involved and that in particular at higher levels, it is beneficial that other cognitive processes are integrated within the system. Organisms with longer time scales and mammals in particular have an advantage in memory and use of experience, whereas this is not an option to a May fly. Again, cognition may be seen as the ultimate constraint.

Ultimately, a rough deduction can be made. Ontic openness may be argued to exist at all levels of biological hierarchy, but can only be calculated. The exact value calculated is dependent on ontological views, but once a system is ontic open in one context or another, it is demonstrated that the phenomenological properties of such systems applies. These properties involve an intrinsic nondirectional evolution of the system. Meanwhile, direction and valuation comes into play when higher levels come into play.

**Table 2.1** A summary of ontic openness at various levels, how the property emerges, what is ultimately constraining it, together with some semiotic perspectives

Level	Ontic openness reached by...	Constraints	Semiotic perspectives
Molecular	Hardly	Mostly simple molecules	–
Macromolecular	Combinatorials calculations of possible constellations of strings of RNA, DNA and proteins	Short time adaptational problem solving at long time scale viable solutions to be produced	Digital code system
Cells and organelles	The combined effect of compartmentalization and specialization of various activities at previous level	Performance regulated from inside while request appears from upper levels	Digital and minor part analog
Organs	Combined effect from lower level expressions and the different type of cells in the organs	Should act as a whole fulfilling demands of the organism	Digital and increasing part analog
Individuals	Organism includes all the previous levels	Fulfilling phenotype demands and adequate semiotic responses	Dominance of analog part for all senses
Populations	Interaction among individuals in (meta-) populations	Space and resources,—mostly intraspecific competition	Increased importance of analog signaling among members, e.g. pheromones
Communities	Intracommunity interactions	Available “niches” and interspecific competitions	Interaction, communication, and cybernetics
Ecosystems	Intra- plus inter population/community interactions	Availability of matter and energy as well as recycling	Higher levels of network interaction, communication, and cybernetics

In order to fully comprehend evolution and development at all scales of biological hierarchy, it seems fruitful and therefore important to add the perspective of ontic openness together with studies of its constraints in future research in the area.

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