11· Simplexity

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Emergence

Inquiring into the form of the process we both inhabit and embody, the semiotic cycle, we are complex systems on a quest for simplicity. The idea of simplicity could only occur to a complex system coping with an even more complex environment.

Through the study of development, evolution and self-organization, we are trying to trace our history backwards, toward the origin of all phenomena. Current physical cosmology traces it back to the Big Bang: we have no way to investigate what could have come before that, or whether there was any time before that. But from that point on, the story of life and mind is mostly about complex systems and processes emerging from simpler ones. This includes the development of guidance systems. For instance, Ursula Goodenough and Terrence Deacon 'suggest that our moral frames of mind emerge from our primate prosocial capacities, transfigured and valenced by our symbolic languages, cultures, and religions' (Goodenough and Deacon 2003, 801). The developments they trace move 'from biology to consciousness to morality' with each level emerging from the one below.

The meaning of a sentence like this one is emergent in the reader's mind. The sentence is made up of words, but these words don't have separate meanings of their own that you can sum up to calculate the meaning of the sentence. Every child learning the language utters meaningful one-word "sentences," but as language develops, words lose the capacity to mean by themselves, and gain the capacity to articulate meanings *in combination with other words*. In the higher stages of language development, it is the sentence in its use and context which endows the words with meaning, not vice versa. It's the relations among the words, and their relations with the language as a whole, and their relations with the situation in which they are uttered – and the consequences (intended or not) of using those words in that situation – that constitute the meaning of the sentence. The whole determines the form of the parts, although of course the sentence cannot exist without its words.

Trying to picture 'emergence' may evoke the image of a *container*, but there is an important difference between the *emergence* of a new level in a systemic holarchy and *emergence* of something from inside a container. A child who has emerged from the womb, or a butterfly from a chrysalis, can do without it from that point on. But life, having emerged from chemical processes, cannot do without chemical processes. Life emerged from the primal seas on this planet and crawled out onto the land, but it cannot do without water. Multicellular organisms emerge from the interaction of cells, and cells from the interaction of molecules, but organisms cannot do without cells, nor can cells do without molecules. Morality cannot do without society, nor can society exist without embodied members and dialogue among them.

The previous chapter introduced Terrence Deacon's (2011) answer to the question of how life and mind could have emerged from simpler physical processes. His theory of *emergent dynamics*

> explains how homeodynamic (e.g. thermodynamic) processes can give rise to morphodynamic (e.g., self-organizing) processes, which can give rise to teleodynamic (e.g., living and mental) processes.… processes at a higher level in this hierarchy emerge from, and are grounded in, simpler physical processes, but exhibit reversals of the otherwise ubiquitous tendencies of these lower-level processes.
>
> — Deacon 2011, 549

Simplicity and complexity are *qualities of order*. Disorder is neither simple nor complex, but 'a complex adaptive system functions best in a situation intermediate between order and disorder' (Gell-Mann 1994, 249). The order of a physical process is both spatial and temporal. The physical *structure* can be analyzed into parts, but the *function* of any part of a system is what it *does*, i.e. what role it plays in the whole self-organizing system. The development of function accompanies the differentiation of the whole into parts: the system grows in complexity as it grows in size.

Since life itself is a process, an account of its origin must begin with the simplest kind of physical *change*. Deacon calls this *orthograde*, defined as 'consistent with the spontaneous, "natural" tendency to change without external interference' (551). One example is the tendency of bodies in a frictionless Newtonian universe to move in straight lines at constant speed. Another is the tendency of an isolated system to approach equilibrium as stipulated by the second law of thermodynamics. But since no system within the universe as we know it is absolutely isolated, it is also 'natural' for bodies and systems to interfere with each other's movements. This can result in 'changes in the state of a system that must be extrinsically forced because they run counter to orthograde (aka spontaneous) tendencies' (549); Deacon calls these *contragrade* changes.

Can we say that some systems (or states of systems) are *structurally* simpler than others, aside from the kind of change they are undergoing? Anything *absolutely* simple would have no *parts* at all. The next simplest structure would have very few parts. The more *functionally different* parts an entity has, the more complex it is. A pile of sand has many parts, but we don't call it complex (nor do we call it a *system*) because there is no functional or structural difference between grains that makes any difference to the structure of the pile – indeed the pile has no structure, unless you count the conical shape it naturally takes as a 'structure.' Likewise consider a closed space where the molecules of a gas have distributed themselves evenly in dynamic equilibrium. If we attempted to label each individual molecule and describe how they are arranged in relation to one another, the description would be extremely long and complicated. Yet this is a "simple" situation in the sense that it has a kind of *symmetry*: there is no relevant difference between any part of the space and any other part, and no significant change over time. This kind of symmetry has to be *broken*, as they say in physics, in order for an *organic* simplicity to emerge. As explained in Chapter 3, all organisms (and more generally, all dissipative structures) are far from energetic equilibrium, and are organized to keep their distance from it so they can go on doing whatever they do. Indeed 'it is the creation of symmetries of asymmetries – patterns of similar differences – that we recognize as being an ordered configuration, or as an organized process, distinct from the simple symmetry of an equilibrium state' (Deacon 2011, 237).

Our idea of simplicity becomes more complex when we consider *morphodynamic* processes, which tend 'to become spontaneously more organized and orderly over time due to constant perturbation.' These are usually called 'self-organizing' but, according to Deacon (2011, 238), 'might better be described as *self-simplifying*, since the internal dynamic diversity often diminishes by vastly many orders of magnitude in comparison to being a relatively isolated system at or near thermodynamic equilibrium.' In an unorganized 'system' such as a pot of water at room temperature, the molecular motion is almost random, events at that scale showing no orderly pattern. If we tried to specify the trajectory of each molecule in the 'system,' the resulting description would be very long indeed (and totally useless for any practical purpose). What appears holistically as the 'simple symmetry of an equilibrium state' shows great 'dynamic diversity' at the level of individual molecules. But if you introduce an external source of heat, patterns of convection are likely to appear which constrain molecular motion within regular patterns, as if the water were responding *systematically* to being perturbed, organizing itself to dissipate the heat as fast as possible, so that the movement within the system is *simpler* to describe. Yet these predictable patterns of change are intrinsic to the substance, not imposed by the external source as the 'perturbing' energy is.

Teleodynamics emerge from morphodynamics when a system begins to take control of its own self-simplifying process. In other words, it begins to develop an internal guidance system to regulate its own economy. Thus arise the cybernetic and semiotic realms of life and mind.

Economy

Semiosis is a mental process inhabited by all sentient beings, and internalized by those capable of learning from experience. Yet it must also be a physical process, powered by energy which every self-organizing process consumes, incorporates and dissipates but does not create. *Observing* this (or any) process also takes time and energy which does not appear in a representation of it such as the meaning cycle diagram. Attention must be *paid*: who pays it, to whom, and in what currency?

Self-organizing systems have to rely on external energy sources in order to sustain their own order against the universal tendency to disorder. Those sources are always more or less limited, and using (consuming) them also produces entropy (see Chapter 3). A guidance system likewise has limited resources with which to make its Model of its World, and therefore has incentive to self-simplify. Although it must be open to information about that World, so that its continuing quest for useful resources may be well guided, the Model has to be simpler than the World it represents. 'Brains have evolved to regulate whole organism relationships with the world' (Deacon 2011, 528), and since those relationships are complex, the brain has to simplify them.

> By the very nature of the translation of the geometry of the properties of the external world into the geometry of the internal functional space, reality is at all times *simplified*. It has to be so; it is the only way the brain can keep up with reality. It must simplify at all times.
>
> — Llinás (2001, 220)

The economy of the nervous system accounts for our tendency to generalize. We draw simplicity from the multiplicity of percepts by sorting them into *types* which we recognize. I look out my window and see a red squirrel – that is, a *typical* member of the species. I don't recognize individual squirrels unless i observe them long and carefully enough to see differences between one squirrel and another. Until then, the squirrel i see is just a *token* of a *type*, so i use the name of the type to refer to any of the tokens. Even an 'individual' squirrel is a generality, relative to the (more strictly speaking) individual occasions of its appearance: it is the continuity of those appearances through spacetime that constitutes the identity of the 'individual' squirrel. We generalize by recognizing typical situations to which we develop habitual responses. In pragmatic terms, the guidance system grows when we combine, separate or improvise responses to novel situations and thus gain self-control. In theoretical terms, our models grow when we *explain* some events as related to relatively simple patterns already embodied in our models.

Adding more categories to your classification system might seem to enrich it, but if it fragments or dissipates your attention, this will not improve your self-control. To do that, your new way of sorting the world into types will have to facilitate an appropriate response better than your old way. The modified model is likely to work better if it *changes* your conceptual toolbox rather than adding to it. Since there are pragmatic limits on the size of this toolbox, new tools need to *replace* the old instead of accumulating. When the tools fit the task better than before, the situation appears simpler because we have a better handle on it.

Here again science appears to be a formalized version of common sense, motivated by a simple faith: according to Einstein/Infeld, the scientist 'certainly believes that, as his knowledge increases, his picture of reality will become simpler and simpler and will explain a wider and wider range of his sensuous impressions.' The simplicity of the model is directly related to the range of experience it will explain. The core faith of science, that the universe is governed by relatively simple and ultimately discoverable rules or laws, probably reflects the unity and closure of the internal model. Any model, if it is to function effectively as a guidance system, must be as single and simple as possible, for though we can imagine many paths, we can realize only one at a time. (As Yogi Berra once said, 'When you come to a fork in the road, take it.') The larger the collection of models, the less portable it is; we can't afford to have a different model for every situation. A reliable guidance system, then, treats the world as a *uni*verse – a single interconnected system – even if it professes to believe that universal laws are figments of imagination. (As we will see in the next chapter, that is the *nominalist* belief as opposed to the *realist*.)

In any scientific hypothesis, then, simplicity is highly desirable. But in the empirical sciences, the typical method of *testing* a theoretical model is to investigate one system or one process at a time, in isolation from the rest of the ambience. Likewise, in everyday learning and informal or preconscious modeling, we always have to resolve the tension between the ideal *model* (which is single, simple and *whole*) and the ideal *method* (which analyzes the universe into clearly defined parts and makes many observations of their many interactions). And in order to make more formal sense of this, we have to arrange the part/whole relationships into hierarchies …

> for indeed one central result of hierarchical organization is greater simplicity; and yet any analytical approach to understanding simplicity always turns out to be very complex.
>
> — Pattee (1973, 73)

To the degree that a theory is well integrated into the guidance system, that theory will be difficult to test separately. Moreover, if the subject we are studying is self-organizing, even defining the parts or processes involved in it (so that we can frame hypotheses about relations between them) can be misleading. 'Holistic aspects that resist formulation in precise terms characterize many organized systems' (Collier 2003, 104).

Practical simplicity

No matter how much energy or material is flowing through a process, it seems simple enough to us if it flows by itself, effortlessly, like a river following the curve of spacetime, gravity doing all the work. Just as a river carves its own channel to facilitate and concentrate its flow, so we channel our energy through habitual practices. A habit is an attractor in behavior space. The simplified situation is *easier* to inhabit, makes fewer demands on our energy and attention. But as long as you're a separate self in a changing landscape, you need to change channels from time to time: everyone 'exercises more or less control over himself by means of modifying his own habits' (Peirce, EP2:413). Modifying our habits will only simplify our situation if they become better adapted to the habits of nature, or what we call the 'laws of nature' – 'nature' being a name for the reality which does its work independently of our control. Science, our collective effort to discover the laws of nature, presumably evolved as a way of simplifying our situation, making it more predictable so that we could adapt to it more easily. But as it evolves, it can begin to take *theoretical* (rather than practical) simplicity as its ideal.

As we saw in Chapter 10, the public, external models and diagrams we use for scientific theorizing are always simpler than the systems they model, just as the brain's internal map of the world is simpler than the world. But theoretical simplicity is not always conducive to practical simplicity. Sometimes our scientific understanding has enabled us to bend natural processes to our own purposes – trying to control nature instead of our own practice – and this has led to unintended consequences. Besides, as Peirce confessed, scientific thinkers can sometimes mistake *logical* simplicity for the more natural, instinctive kind.

> Modern science has been builded after the model of Galileo, who founded it on *il lume naturale* [the light of nature]. That truly inspired prophet had said that, of two hypotheses, the *simpler* is to be preferred; but I was formerly one of those who, in our dull self-conceit fancying ourselves more sly than he, twisted the maxim to mean the *logically* simpler, the one that adds the least to what has been observed … It was not until long experience forced me to realize that subsequent discoveries were every time showing I had been wrong,—while those who understood the maxim as Galileo had done, early unlocked the secret,—that the scales fell from my eyes and my mind awoke to the broad and flaming daylight that it is the simpler hypothesis in the sense of the more facile and natural, the one that instinct suggests, that must be preferred; for the reason that unless man have a natural bent in

> accordance with nature's, he has no chance of understanding nature, at all. … I do not mean that logical simplicity is a consideration of no value at all, but only that its value is badly secondary to that of simplicity in the other sense.
>
> — EP2:444

As a logician, Peirce was well acquainted with the logic which strives to reduce the laws of nature to the simplest possible formula. But as a working scientist, he learned that 'every advance of science that further opens the truth to our view discloses a world of unexpected complications' (EP2:444). Logical simplicity may turn out to be an illusion, while the simplicity of the easy, 'natural' hypothesis is more conducive to the long-term learning process. Because our instincts have evolved along with us, we relate most easily to the level of complexity which we ourselves embody. For instance, being animals, we are naturally interested in animals; asked to see an inkblot 'as' something specific, we are more likely to see animals than inanimate objects (Bartlett 1932, 37). Having been tested and refined by natural selection itself, the eye of our instinct tends to be better at seeing the real patterns in nature than the eye of logical analysis. But then instinct also urges us to enlist the aid of reasoning in the quest for truth, and at that point logic becomes indispensible.

The case of Galileo also illustrates the difference between a hypothesis that seems natural to a scientist and an idea that seems natural to those who rely on the conventional wisdom of their time (such as the belief that all the heavenly bodies revolve around the earth). Was it simple to see that night and day take turns because the earth turns? To see that the tilt of the earth's axis gives us the seasons as we orbit the sun? Modelling the solar system by placing the sun at the centre certainly made it simpler to explain the observed motions of the planets; the heliocentric model turned out to be a powerful attractor in theoretical space. But it took a mental leap to approach it from the more habitual attractor of taking one's own point of view as the centre of the universe.

The instinct of the genuine scientist is to trust observation of nature more than conventional belief about it. He also realizes that the simplicity of a hypothesis does not make it true: we still have need of deductive logic to generate predictions from it, and inductive logic to see whether the observed facts confirm those predictions. The economy of research requires us to select hypotheses for testing, since we don't have the resources or the time to test every wild guess about the nature of nature. Investigation therefore begins with the hypothesis that instinctively seems worth checking out – and then typically turns to analysis, or the quest for the logically *elementary*.

Conceptual or theoretical simplicity tends to involve reducing a system or process to its simplest parts or *elements*, those which are not themselves composed of parts. In chemistry, for instance, the elements can combine to form compounds but are not themselves compounds: they can't be resolved into smaller parts by chemical means. But the elements in chemistry are not the same as the elements of physics, or biology, or psychology – or *phaneroscopy*, which studies the 'elements of the phaneron' (introduced in Chapter 5).

In each special science, the simplest structural account of a complex system would explain how all its elements relate to one another to constitute the system. In an essay 'On the Method of Theoretical Physics,' Einstein made this observation:

> It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience.
>
> *Philosophy of Science*, Vol. 1, No. 2 (April 1934), p. 165

This is one expression of the precept often called 'Ockham's razor': *Thou shalt not invoke a complicated explanation when a simpler one is adequate.* But the *adequacy* of a theoretical explanation is inseparable from its *honesty*, its refusal to ignore the facts based on actual observation: if these contradict the implications of the model, then the model is probably *too* simple, no matter how well it may explain some other facts.

Phenomenal and semiotic simplicity

The principles of inquiry itself are common to all genuine sciences, because they all deploy the basic elements of reasoning, which are even more basically the elements of semiosis. The various kinds of phenomena observed by the various special sciences also share the elements of all possible phenomena – which brings us back to what Peirce called the 'elements of the phaneron.' How do *those* elements relate to the observations of Einstein and Llinás above?

What Llinás called *translation of properties of the external world into internal functions*, or internal *representation* of the external world, is represented in the gnoxic diagram as *perception* (or simply *ception*). To the extent that it really represents the *external* world, a 'datum of experience' offers some resistance to conscious control. That's why we call it a *datum*, which means in Latin that it is *given*. It is undeniably present: the mind cannot refuse the gift, although we can deny or distort the memory of it. *Mind* here simply means all that anything can *appear* to, and *experience* (as in Chapter 7) designates a crossing or 'clash' between the internal and external worlds.

Any *phenomenon*, anything that appears, has this quality of being 'given.' At this point, there is no difference between 'mental' and 'physical' phenomena. But by the time it has been singled out for attention as *a* datum (or a *percept*), it has already presented itself as individually *other* than whatever else was present to the mind at the time. Its otherness, or Secondness as Peirce called it, is an element of the phenomenon. Its having any quality at all (apart from its relation to anything else), its Firstness, is also an element of the phenomenon. This felt quality or feeling is already simpler than anything analysis can produce.

> A feeling so long as it remains a mere feeling is absolutely simple. For if it had parts, those parts would be something different from the whole, in the presence of which the being of the whole would consist. Consequently, the being of the feeling would consist of something beside itself, and in a relation. Thus it would violate the definition of feeling as that mode of consciousness whose being lies wholly in itself and not in any relation to anything else. In short, a pure feeling

> can be nothing but the total unanalyzed impression of the *tout ensemble* of consciousness. Such a mode of being may be called *simple monadic Being.*
>
> CP 6.345 (c. 1909)

As we heard from the *Blue Cliff Record* at the end of Chapter 10: *If you want to become acquainted with direct perception, it is before mention is made*. But we can only mention a phenomenon, or record it, or recognize it, because it is related to other phenomena in some way other than mere otherness. Systems and processes evidently do relate to other phenomena, and some processes and relations *continue* over time, which shows that Thirdness is also an element of the phaneron. Peirce made this point in 1878 by using the example of a melody or 'air':

> It consists in an orderliness in the succession of sounds which strike the ear at different times; and to perceive it there must be some continuity of consciousness which makes the events of a lapse of time present to us. We certainly only perceive the air by hearing the separate notes; yet we cannot be said to directly hear it, for we hear only what is present at the instant, and an orderliness of succession cannot exist in an instant. These two sorts of objects, what we are *immediately* conscious of and what we are *mediately* conscious of, are found in all consciousness. Some elements (the sensations) are completely present at every instant so long as they last, while others (like thought) are actions having beginning, middle, and end, and consist in a congruence in the succession of sensations which flow through the mind. They cannot be immediately present to us, but must cover some portion of the past or future. Thought is a thread of melody running through the succession of our sensations.
>
> EP1:128-9

If we analyze time minutely enough, even the physical sensation of a single note takes time, because it is produced by a *vibration* of a certain frequency – as indeed are the sensations of light and color as well, although we have to use very special instruments to measure the frequency of those vibrations. Peircean phenomenology, which 'ascertains and studies the kinds of elements universally present in the phenomenon; meaning by the *phenomenon*, whatever is present at any time to the mind in any way' (EP2:259), needs no special instruments, but does need close attention to the phenomenon which *is* the experience. It shows that time, continuity and mediation, all manifestations of Thirdness, are elements of all phenonomena because their presence to the mind cannot be instantaneously immediate. Peirce wrote to James in 1904: 'My "phenomenon" for which I must invent a new word is very near your "pure experience" but not quite since I do not exclude time and also speak of only one "phenomenon"' (CP 8.301; the new word turned out to be 'phaneron').

As we saw in the previous chapter, Peirce pointed out that 'continuity, regularity, and significance are essentially the same idea with merely subsidiary differences' – the idea of Thirdness. As *elements*, Firstness, Secondness and Thirdness must all have the elementary kind of simplicity. This is not so obvious in the case of Thirdness as it is with the other two.

> It is certainly hard to believe, until one is forced to the belief, that a conception so obtrusively complex as Thirdness is should be an irreducible unanalyzable conception. What, one naturally exclaims, does this man think to convince us that a conception is complex and simple, at the same time! I might answer this by drawing a distinction. It is complex in the sense that different features may be discriminated in it, but the peculiar idea of *complexity* that it contains, although it has complexity as its object, is an unanalyzable idea. Of what is the conception of *complexity* built up? Produce it by construction without using any idea which involves it if you can.
>
> — Peirce, EP2:176

Semiosis as re-presentation epitomizes Thirdness as mediation, just as time epitomizes continuity. But semiotic closure can only occur in systems complex enough to be self-organizing, and only those employing symbols in their self-guidance systems can have a *concept* of semiosis. The concept has to simplify the actual process in order to *represent* it adequately, so that its interpretant serves the purposes of the system hosting the concept. To conceive of anything, we attend to its essential features, its essential relations with the rest of the universe, ignoring irrelevant differences between one instance and another. Then, by an act of what Peirce called 'hypostatic abstraction,' we give it a name, which can now become part of a *general* sign, one that leaves it up to the interpreter to select any individual instance of the type indicated as its object. The general term can thus adequately represent all instances of it – even though no user of the concept is actually acquainted with all of them – because the logical breadth of the term includes them all. (Recall Chapter 10 on the logical relations between breadth, depth and information.)

However, the simplicity we gain by generalizing usually comes at the cost of some vagueness. Individual objects are determinate in more ways than their common names can represent. Terms in habitual use are simple in the practical sense but rarely so in the logical sense. Since we can't always afford the depth of attention that precise language demands, we often have to settle for a degenerate sort of simplicity. Polyversity, or diversity of usage over time between users, compounds the difficulty of achieving pragmatic simplicity with symbols.

Honest inquiry aims to achieve a maximum of generality with a minimum of vagueness. By generalizing, i.e. representing individual facts as instances or *tokens* of a *type*, we simplify our theoretical models of the world. By closure of the action-perception cycle, this in turn simplifies our practice, by directing our attention and thus conserving energy that otherwise might be wasted in activities that don't matter. Stepping back to observe the cycle as if from the outside, we exemplify the simplifying tendency, mapping the flow of time onto cycles, and the cycle onto a circle, the simplest of closed forms.

If we ask whether a percept is *simple* before it becomes an object in semiosis, the answer will depend on what kind of simplicity we are talking about. Being *given*, and thus requiring no effort to produce, the percept is certainly simple as far as *practice* is concerned. But in *theory*, perception is already semiosis, part of a meaning cycle which is irreducibly complex. This cycle is doing the self-organizing, self-guiding work that produces percepts as well as concepts and precepts. All of these, as well as the system inhabiting the cycle, can be viewed as embodiments of the energy flowing through the system and through the larger systems in which (as a holon) it must be embedded. There is no semiosis, and no system, without the flow of energy.

Energetics

As we saw in Chapter 4, Peirce spoke of physical matter as 'mind hidebound with habits' – this was part of his 'synechism' (introduced in Chapter 8), which rejected the idea of an absolute distinction between *mind* and *matter*. Later Einstein made a similar point about the distinction in physics between *energy* and matter: he showed that the energy 'bound' into a unit of matter is equivalent to its mass multiplied by a very large constant (the speed of light squared). This allowed us to account for the transformation of matter into energy in the nuclear reactions which occur in the sun and thus power life on earth. (It also allowed us to build new weapons of mass destruction, over the protests of Einstein and other scientists … but that's another story.)

Combining Peirce's synechism with Einstein's relativity, we can regard matter as a concentrated, habit-bound embodiment of energy. If the recursive self-organizing processes which generate and constitute living systems determine the *form* of those embodiments, energy is the *matter* informed and transformed by those processes. In other words, organized physical structures are embodiments of energy which vary according to the systemic processes which produce them.

> All systems transform energy from one form to another, a process that is called 'work.'
>
> — Odum and Odum (2001, 63)

The self-organizing process aims to optimize itself by consuming energy from external sources, internalizing some of that energy as its own structure and using some of it to do its work.

Thus every organism is on a quest for energy in some form that is useful to it (i.e. usable for its work or its self-organization). Once consumed, the energy is no longer available for that use; in thermodynamic terms, it has been *dissipated*. Consumers of energy are therefore called (by Prigogine) *dissipative structures* – a category even more general than life itself, for it includes all living things plus proto-entities such as hurricanes, which develop through a 'life cycle' vaguely resembling that of a plant or animal. (Their individuality is reflected in our habit of giving them proper names, such as *Katrina*.) The cognitive or meaning cycle emerges when this more general life cycle is realized in a system with an internal model which guides its behavior and directs its attention.

Dissipative structures could be defined as entities which consume energy and use it constructively. Organisms reach out for energy 'packaged' in a form they can consume. The consumed energy is then converted into an internally useful form. Your food, for instance, is repackaged by digestion into a form that your cells can use as a power supply for *their* work, which in turn sustains the structural basis of *your* work. Your 'habits' and 'structures' are functionally equivalent in the sense that their relative permanence or stability depends on some of the energy you consume being used to reform (modify) or repair them. These habit-structures, of course, constitute the internal guidance system which directs your external or observable behavior. It follows that you are a consumer of *information* (defined as whatever *informs* your guidance system) as well as an energy consumer. Indeed the process described in this paragraph is essentially the same as the semiotic cycle, and can be visualized with the same diagram labelled in a slightly different way (e.g. 'quest' and 'consumption' for 'practice' and 'perception'). Consumable information is made up of signs, which are products of a semiosic process, which turns energy into meaningful forms. But signs are meaningful only when they are *recycled*, i.e. when they generate an interpretant which can in turn generate *another* interpretant. In semiosis, 'consumption' is recycling.

If eveything that counts is a transformation of energy, then energy is the real currency of the real economy. On this basis, ecologist Howard Odum has developed a consistent way of evaluating the embodied energy that constitutes the real wealth of Planet Earth. Odum's term *energetics* (Odum 2007, 34) is a more suitable term for this branch of science than the conventional term *thermodynamics*, because it is all about energy and only partially about heat (which, being constituted by random molecular motion, is a relatively degraded or disorganized form of energy). We will therefore use the term *energetics* from this point on.

In Odum's formulation above, *work* is the generic name for a process which changes one form of energy into another. Energy is the matter of all systemic processes, yet it also *does* all the work, since it powers every process. Indeed, as we have seen (Chapter 3), we have no way of measuring (or even defining) *energy* except in terms of the observable work it does. Thus both systems and processes consist of energy transforming itself. Systems are more or less concentrated embodiments of energy, inhabiting processes which themselves take various forms according to the habits of the systems in which they are involved. These habits are in turn informed by semiosic processes, which channel energy into the channeling of energy. Thus information as embodied in various forms is a concentrated form of energy, while information as a *process* – namely *Thought*, in the Peircean sense of that word – is a kind of meta-energy acting as a formal cause of other processes.

Sometimes work involves transforming physical and/or semiotic matter from one form to another, but systems are themselves embodiments of energy. We see the more habit-bound bodies as *inert*, the more spontaneously active as *alive* – but all are themselves products of work which requires, transforms and consumes energy. Does work matter? All work makes a physical difference, but it can only *matter* by making a semiotic difference to some teleodynamic system which in itself embodies, transforms and consumes energy.

The processes that make up the biosphere consume or transform energy which comes ultimately from sources outside of it, mostly from the sun or the hot interior of the earth. But the transformations occur in a hierarchy like the 'food chain,' in which some systems consume others to embody energy in more concentrated forms. By measuring the energy circulating in various forms through the self-transforming processes of the biosphere, Odum (2007) shows a way to quantify the energy economy, giving us a measure of *real wealth*.

> Food, shelter, clothing, fuels, minerals, forests, fisheries, land, buildings, art, music and information are *real wealth*. Money by itself is not. Money is circulated among people who use it to buy real wealth.
>
> — Odum and Odum (2001, 91)

Money simplifies exchange by reducing value to a common currency. But the money economy is wholly dependent on the energy economy and reflects it in a partial and distorted way, because it circulates only within social systems (under the influence of artificial and unstable value systems), while energy circulates through *all* systems. As a better measure of real wealth or 'natural value,' Odum (2007, 69) proposed embodied energy or *emergy*, defined as *the available energy of one kind previously used up directly or indirectly to make a product or service*. This measure simplifies the comparison of natural values and allows us to relate all the forms of energy in a series of energy transformations to one form of energy. If that one form is solar, for instance, we can calculate the *transformity* of a process thus:

Solar transformity = (Solar emergy/Time) / (Energy/Time)

Since Energy over Time is called *power*, Emergy/Time is called *empower*. Transformity can then be expressed in Solar emcalories per Calorie, or Solar emjoules per Joule (calorie and joule being units of power). This allows us to quantify the position of each product or service in the universal *energy hierarchy*. With each transformation in a systemic process, transformity increases while energy decreases. For instance, when photovoltaic cells convert sunlight into electricity, the energy output is less than the input, but electrical power has higher transformity, and is available to do work that solar radiation cannot do directly. Information has even higher transformity: it takes a lot of energy to produce and has almost no power to drive further processes, but it makes a bigger difference to the *quality* of those processes than any other embodiment of energy, and takes very little additional energy to replicate and re-use.

> At the top of the energy hierarchy is information, which depends on a copying cycle. Widely shared information

is the highest of all transformities.

Odum (2007, 97)

Life cycles

Odum's formulation of the energy hierarchy simplifies our model of the planetary guidance system, and of course his schematic diagrams have to simplify the processes they represent, limiting the 'window of attention' to the most relevant and measurable parts of those processes. We are biased by our embodiment, which informs the values which define what counts as *work* for us by determining what we can consider *useful*. But since embodiment is itself a process, some basic values of a teleodynamic system change as one moves through the 'life' cycle (placing 'life' in quotation marks because this cycle is common to all dissipative structures, some of which are not alive). The meaning cycle, the engine of explanation, finds itself to be a wheel within this wheel, a specific development of this more general cyclic pattern.

Dissipative structures range in scale from a single cell to a whole ecosystem (or weather system), or perhaps to the whole planet (Gaia). All these systems follow a developmental path which in its simplest form has three stages, which i will call *youth, maturity* and *senescence.* The youthful (or 'immature') stage is the most energetic and flexible in behavior: as lots of energy is flowing through a relatively small system, it lives, learns and grows *fast.* As it acquires more "experience" (definite habits or structures) while growing in size, it becomes more differentiated, articulate and fine-tuned in its behavior, more "informed" and "expert." (Differentiation within a social system will naturally be seen by its members as *individuation*.) But it also becomes less flexible as it accumulates 'frozen accidents' from its history; as the cycle draws toward a close, structure and behavior become more rigidly defined (more *fast* in the sense of 'fixed'). The development process always moves from youth toward senescence as the entity engages with its world in its quest for consumable energy packages. Each closure of the learning cycle carries the dissipative structure another step along the larger-scale path of its life cycle, toward the final self-definition of a closed structure.

Of course that 'perfect' closure is never realized, because the structure gets recycled when it becomes too rigid in its habits to cope with the ever-changing perturbations coming at it from the environment. According to Salthe (1993), senescence results from (or correlates with) information overload. An organism, when it can no longer "go with the flow" without losing its integrity, simply stops, dies, and becomes food for other organisms. An overmature ecosystem, when stressed, is more likely to revert to an immature form, its delicate web of interrelationships replaced by fast-growing invasive species. A glacier melts, a river chokes itself with the silt picked up in its youth and turns into a delta or bog, a hurricane 'blows itself out' and dissipates, a bacterium divides into two – there are many forms of recycling.

Entities tend to be partial to their own wholeness – nobody wants to be recycled prematurely. Mature structures can avoid this fate by maintaining a reserve of flexibility, which means keeping some of their unused options open. A perfectly efficient structure would be perfectly senescent, and its behavior perfectly mechanical, never making errors because it never tried anything new. Some neuroscientists have suggested that inefficiencies in brain function and uncertainties in reasoning may have an important biological function. 'Randomness introduces variability in the way in which an organism interacts with its environment. In particular, a constant process of "shaking up" the organization of input would allow for new solutions' (Metzinger 2003, 246). When this constant process takes over the foreground of perception, perhaps because available sense data are ambiguous or overwhelming, the result is hallucination – a phenomenal but non-consensual experience. But we are also capable of deliberately shaking up our perceptual and conceptual habits by creating and attending to works of art. They can provide both diversion and healthy diversity as alternative or virtual realities.

Robert Ulanowicz (1997) demonstrates the crucial function of diversity in the life cycle of an ecosystem. He begins with the principle that a mature ecosystem tends to maximize the orderly dissipation of the energy available to it, and he uses information theory to devise a way of measuring this characteristic, which he calls 'ascendency.' (He spells it differently from 'ascendancy' because that term suggests the dominance pattern of a social hierarchy, which is not the kind of hierarchy at work in ecosystem development). Maximum ascendency or orderliness in an ecosystem would amount to a niche for everything and everything in its niche, with each component perfectly adapted to its niche and perfectly efficient in its energy transactions. But this goal can never be fully realized because there are always 'inefficient, incoherent, redundant events and processes' going on in it, and the measure of these he calls 'overhead.' All systems appear to strive toward ascendency and closure, but too much success would undermine their health, their wholeness.

> In particular, the endpoint of senescence, owing as it does to insufficient overhead, engenders in us a new appreciation for the *necessary* role that inefficient, incoherent, redundant, and ofttimes stochastic events and processes play in maintaining and even creating order throughout the lifetime of a system (Conrad 1983). Our human inclination is to seek an ever more orderly and efficient world – which is only natural, considering the degree of chaos and mayhem that characterizes human history. But our intuition tells us that there also can be too much of a good thing. We often speak of individuals' lives and whole societies that are too rigidly structured as being 'suffocating.' As we have seen, ecosystems, too, can create too much structure and thereby become 'brittle.' Thus, efficiency can become the road to senescence and catastrophe.
>
> — Ulanowicz (1997, 92)

Evolutionary biology offers the similar concept of '*polymorphism*: the positive maintenance of variety for variety's sake' (Dawkins 2004, 54). But Ulanowicz has gone further in formulating what Taoist sage Chuang Tzu called 'the use of the useless.' So does Peirce, with regard to science:

> True science is distinctively the study of useless things. For the useful things will get studied without the aid of scientific men. To employ these rare minds on such

> work is like running a steam engine by burning diamonds.
>
> — Peirce, CP 1.76 (c. 1896)

Of course, some of these useless theoretical discoveries turn out to have practical applications that we later find extremely useful. A similar pattern turns up in the gospels:

> Jesus said, 'Show me the stone which the builders have rejected. That one is the cornerstone.'
>
> — *Thomas* 66 (Lambdin)

The pattern outlined by Ulanowicz in terms of *ascendency* and *overhead* also turns up in cognitive cycles – even in computer models of creativity, such as those developed by Douglas Hofstadter and his colleagues in the Fluid Analogies Research Group. They investigated creative mental processes such as analogy-making by creating and running software models of them. One, called *Copycat*, employed a flexible conceptual network called a 'slipnet'; the design incorporated enough randomness to enable a trial-and-error process, but also included biases which enabled the process to reach closure.

> The important thing is that at the outset of a run, the system is more open than at any other time to *any* possible organizing theme (or set of themes); as processing takes place and perceptual discoveries of all sorts are made, the system loses this naive, open-minded quality, as indeed it ought to, and usually ends up being 'closed-minded'—that is, strongly biased towards the pursuit of some initially unsuspected avenue.
>
> — Hofstadter and FARG (1995, 228)

Thus the life cycle of a 'run' is like the cycle of a dissipative structure, progressively approaching closure – but the continued survival of the system may depend on its ability to reiterate (recycle) this process *and get a different result*. Once again openness complements closure to generate the complexity and creativity of life.

In a complex guidance system, such as a nervous system, fallibility of the parts turns out to be necessary to the viability of the whole. Llinás (2001, 264) summarized Warren McCullogh's explanation of how 'reliability could arise from nonreliable systems' as follows:

> He felt that reliability could be attained if neurons were organized in parallel so that the ultimate message was the sum of the activity of the neurons acting simultaneously. He further explained that a system where the elements were unreliable to the point that their unreliabilites were sufficiently different from one another would in principle be far *more* reliable than a system made out of totally reliable parts.

This is part of Llinás's argument that homogenization and unanimity tend to make the whole system more fragile. If this principle applies to the political economy of the planet, it would suggest that the kind of globalized corporate culture which emerged in the 20th century was lagging behind the scientific insights developed in that period. Turning to the 21st Century, that global culture was showing its senescence by increasingly closing its collective mind to the insights emerging from its own research – such as the damage done to the climate and biodiversity of the planet by excessive human consumption.

Design and determination

Physical complexity and semiosis tend to follow similar paths of development. A complex system generally starts out *vague*, but vaguely determined to become more *definite* as it develops; and this 'determination' is essentially what Hoffmeyer (2008) calls *semiotic causality*. As systems, situations or stories develop (unfold), actualizing and specifying some of the possibilities latent within them, their component events and structures are defined, articulated, with ever more precision. What was only implied becomes explicit. Likewise in the practice of language, the meanings of terms grow more definite through their use in actual contexts. When those meanings are later specified (by means of other words) in a dictionary, acceptance of that *definition* is based inductively on observed usage – a task that can never be quite *finished* as long as the language is alive, since usage continues to evolve. But terms can also be formally defined in order to specify their use (and reduce vagueness) in reasoning.

The roots *-fin-* and *-term-* both refer to *limits* or *boundaries*; to *define* a word (or term) is to *determine* its subsequent usage in that discourse, i.e. to fix implicit or explicit boundaries within which it can be used. Once it becomes completely fixed, the determination process has reached its end: the spirit or energy which gave life to it has been dissipated. Time is the continuous disappearance of possibilities into the past, either through irrevocable closure as actual events, or through vanishing into the mist of the might-have-been.

Our very lives are processes involved in, and constrained by, other processes. We value things, or consider them useful, according to their involvement in some process we inhabit. But our habits and implicit values are either preconscious or postconscious. They are the psychical remnants of the same self-simplifying process which generates physical complexity.

The work done by semiosis is information, a process which transforms the guidance system (i.e. the habits) of the system thus informed. Considering information as product rather than process, it is embodied energy which, when incorporated in a continuing semiotic process, can alter the courses of subsequent energy flows. The more complex information is (either as process or product), the more attention it requires to do its work, on top of the energy consumed by the work. Any system capable of attention will therefore value cognitive simplicity, to the extent that its attention is limited. Science is a special case of this, and the economy of research (Peirce, CP 1.85 etc.) must take into account the limitations on energy and attention as well as financial limitations.

The value of simplicity, and the form it takes, depends on the kind of complexity embodied in the system. Transformity accounts for practical value, but what about theoretical or esthetic value? We don't value one work of art over another because more energy went into its making, just as we don't value a theory for its practical applications alone. What makes it good for us beings engaged in *semiotic* work is not what keeps us alive but what makes life worth living. The value of semiotic work is its *significance*, and our sense of that arises from our instinctive sense of what we are here to do – the role we play in the drama of creation. Humans, for instance, are at their best as a species when carrying out the specifically human mission.

> Animals of all races rise far above the general level of their intelligence in those performances that are their proper function, such as flying and nest-building for ordinary birds; and what is man's proper function if it be not to embody general ideas in art-creations, in utilities, and above all in theoretical cognition?
>
> — Peirce (EP2:443)

Peirce's question here is a rhetorical one, but his work as a whole does suggest the reasoning (and the instinctive feeling) behind his threefold statement of 'man's proper function.' His preference for 'theoretical cognition' seems to echo a parable of Pythagoras:

> Life, he said, is like a festival; just as some come to the festival to compete, some to ply their trade, but the best people come as spectators, so in life the slavish men go hunting for fame or gain, the philosophers for the truth.
>
> Kirk and Raven 1957, 228

The Greek word for contemplation, θεωρία, shares its root with *theatre* and *theory*. In the same vein, Gregory Bateson observed that life is 'a game whose purpose is to discover the rules, which rules are always changing and always undiscoverable' (Bateson 1972, 19-20). Peirce might not agree that the rules are undiscoverable, but he would agree that even if we could ever realize the ideal of discovering them, we could never be sure that we have perfected our knowledge. In defining 'logical truth' for *Baldwin's Dictionary*, he stipulated that the truth of a proposition 'essentially depends upon that proposition's not professing to be exactly true.' This points to the *organic* quality of propositions, which they inherit from the life of semiosis.

Two chapters ago, we considered the Einstein/Infeld description of the physicist as 'somewhat like a man trying to understand the mechanism of a closed watch,' and some disadvantages of choosing the artificial mechanism of a watch as a symbol of the natural order. Why then was that choice made? One possible reason is that the watch has been conventionally used to represent complexity of structure ever since Newton's celestial mechanics presented us with a 'clockwork universe' – so rather than think up a new one, Einstein and Infeld simply went along with convention. Besides, Einstein and Infeld were writing in 1938, when physics was flushed with its success in modeling both celestial and quantum mechanics. The one kind of thing it was unable to model very well was the *living* kind. Since then, science has taken a few tentative steps toward explaining the physical basis of life; but this has meant leaving the clockwork universe behind, and venturing into the realm of complex *processes*. Yet it's the same old quest for theoretical simplicity that leads to the science of complexity.

The irony of the watch analogy is that the very purpose of a watch is to tell the time, and *time* – certainly an element of every process – is ignored when we focus on the *structure* of the watch. It can certainly be analyzed into many different functional parts, just as an organism can. But a watch does not *develop* those parts or those functions: they are specified and assembled by an external agency, the watchmaker. You can't *grow* a watch, because it is not integrated from within. An organism is alive because its integrity and its parts, with their structures and functions, mutually define each other through the process of development. This entails that 'a living organism taken apart suffers the Humpty-Dumpty problem' (Deacon 2011, 164). But a machine, no matter how complicated, is not a complex system in that sense. Since the parts are not mutually determined, you can remove or replace them without affecting the other parts, and they don't spontaneously change or decay when you take them out of context. That's why a heart transplant is much more difficult to achieve than, say, a carburetor transplant. But while the 'transplant' metaphor refers originally to moving a *whole* plant from one place to another, the 'transplanting' of *parts* from body to body is a symptom of our technological tendency to treat the body mechanistically. A more holistic medical science would respect the complexity of the body by investigating the *causes* of heart disease, so that it could be prevented by a change of habits (such as diet and exercise) – in which case surgical intervention would rarely be needed.

Our choice of metaphors is virtually a choice of the diagrams on which our reasoning will be based. Peirce's threefold classification of human purposes (art, utility and theoretical cognition) is organically related to his division of the *normative sciences* (those which set up standards by which work is guided) into *logic, ethics* and *esthetics* (EP2:199). Logic as a normative science is the ethics of reasoning, which implies that the logically good (i.e. *truth*) is a species of the ethically good. This in turn 'appears as a particular species of the esthetically good' (EP2:201), the highest or most general good.

Peirce did not claim any expertise in esthetics, but the investigation of it in his Harvard Lectures of 1903 describes the esthetically good in terms of the relation between simplicity and complexity:

> In the light of the doctrine of categories I should say that an object, to be esthetically good, must have a multitude of parts so related to one another as to impart a positive simple immediate quality to their totality; and whatever does this is, in so far, esthetically good, no matter what the particular quality of the total may be.
>
> EP2:201

If it is the relations among the parts that make an object esthetically good, the object must be at least complex enough to have parts. An object with no parts at all would be perfectly simple, but would be neither good nor bad esthetically. We could say that the esthetic goodness or 'beauty' of an object, or a process, is its *simplexity*.

But is this an *objective* quality, really inherent in things regardless of whether anyone sees them, or is 'beauty in the eye of the beholder,' as they say? The next chapter will address this question.