# Evolutionary Systems

## Biological and Epistemological Perspectives on Selection and Self-Organization

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# SPONTANEOUS ORDER, EVOLUTION, AND AUTOCATAKINETICS: THE NOMOLOGICAL BASIS FOR THE EMERGENCE OF MEANING

## INTRODUCTION

Something has meaning when it has the property of "information about" some part of the world with respect to an end or ends of some intentional system or agent. Intentional systems are end-directed systems, but not all end-directed systems are intentional. Not all end-directed systems require information about or meaning to determine their actions towards their ends. We need not invoke intentionality, or meaning, for example, to explain the flow of a river down a slope, or the flow of heat down a temperature gradient from a hotter to a cooler region because these processes are explicable in terms of local physical potentials and fundamental laws. On the other hand, when a bird flies above the Earth, a bacterium swims up a concentration or chemical gradient, or a human drives a car, takes a plane, or moves a bit of food from her plate to her mouth, the action is seen to go in directions that are different, or orthogonal, to processes taken to causally follow from local physical potentials (the "orthogonality condition"). Such behavior is determined by information about the paths to ends, not by local potentials and it is these systems we call intentional.

The orthogonality condition provides some immediate clues to the nature of intentionality and meaning. To begin with it provides a dimension that has progressively increased during the course of planetary evolution. This is interesting enough because orthodox evolutionary theory (Darwinian theory) can supply no ordinal measures with respect to the progressive nature of evolution, but it is even more interesting by virtue of the fact that it refers to the epistemic or cognitive function of terrestrial evolution writ large, again something that is well beyond the scope of Darwinian theory. It suggests a principled basis for recognizing the commensurability between psychology, biology and physics, and hence between knower and known as part of a general evolutionary or universal process.

The most significant clue to the origin and nature of intentionality and meaning is the distinctive property that defines the orthogonality condition itself. In particular, the fact that intentional dynamics work in directions and over lengths of time different from those determined by local physical potentials makes it clear that intentional systems define dimensions of space-time that are determined differently from those systems determined by local potentials. What might this mean? According to Boltzmann's interpretation of the second law of thermodynamics the transition from disorder to order, the filling of ordered dimensions of space-time is infinitely improbable. What then is the basis for the epistemic or psychological dimension which appears thus to actively work against the apparent universality of physical law? In this paper I will show that contrary to the older view which falls out of Cartesian metaphysics, the epistemic dimension is not only fully commensurable



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with universal principles, but a direct manifestation of them.

## CARTESIAN METAPHYSICS, THE RISE OF MODERN SCIENCE AND THE POSTULATES OF INCOMMENSURABILITY

Although the physics of Newton eclipsed the physics of Descartes it was the latter's dualistic metaphysics that provided the ground on which the former was able to flourish, and because psychology and physics were defined at their modern origins by Descartes, he is often referred to not only as the father of modern philosophy but the father of modern psychology and physics as well. What Cartesianism effected with its dead mechanical, or clock-work, view was a means for the religious authority of Descartes' time to see science within a context it could accept. Humans were seen sitting dualistically outside the clock-like world learning the laws of physics to manipulate it towards their own, and hence, as privileged creations on Earth, towards divine ends.

The main point with respect to this paper is that Cartesian dualism literally took the active epistemic dimension out of the physical part of the world by defining physics and psychology by their mutual exclusivity (call this "first postulate of incommensurability", Swenson, 1997a, 1997b). According to this postulate the world was divided into an active, purposive, perceiving "mind" (the "free soul", "thinking I", "Cartesian ego", or "self") on the one hand (the psychological part), and passive, "dead", purposeless "matter" (the physical part) on the other. The physical part, defined exclusively by its extension in space and time, was seen to consist of reversible, qualityless, inert particles governed by deterministic causal laws from which the striving mind, seen as active boundless and without spatial or temporal dimension, was immune.

An immediate implicate of this view was that spontaneous ordering in general, and intentionality and meaning in particular were eliminated from the physical world by definition, and needed to be extra-physically imposed from the outside. Another immediate implicate, certainly an unintended one, was that the epistemic and physical parts of the world were logically forbidden from interacting — the problem of Cartesian interactionism. For one part to interact with another it would have to violate the postulate of incommensurability defining the dualism. For example, for "mind", supposedly without spatial or temporal dimension, to act on matter defined in space and time, it would have to become defined in space and time at the point of interaction. But then part of mind would be defined in space and time and part would not. How does the part that is not then interact with the part that is without itself becoming defined in space and time? The problem leads to an infinite regress until mind takes on the properties of matter and the dualism is demolished.

Leibniz recognized this central problem of Cartesianism, and dualism in general, by anticipating the law of energy conservation (the first law of thermodynamics). For one thing to interact with another requires something conserved over the interaction, and if something is conserved over the two things or processes they are, at some level, part of the same thing. Without a conservation the two would be truly incommensurable — two separate worlds without any possible relation or causal connection. Descartes' theory of perception which had mind perceiving itself when coupled with the intractable problem of interactionism, made the epistemic dimension a closed circle with no way in or out (the "Cartesian circle") — the subjective simply given with no basis for its existence or meaningful connection with anything other than or beyond itself.

Cartesian metaphysics came full-blown into modern biology with Kant who, arguing that the active, end-directed striving of living things, could not be adequately accounted for as part of a dead, reversible mechanical world, promoted a second major dualism (the "second postulate of incommensurability", Swenson, 1997a, 1997b), the dualism between biology and physics, or between living things and their environments (Swenson & Turvey, 1991). This argument for the autonomy of biology from physics is still promoted today by leading proponents of Darwinian theory (e.g. Mayr, 1985). "Darwin", in Lewontin's words, following the tradition of incommensurability, "completely rejected [the] world view (...) that what was outside and what was inside were part of the same whole system (...) and replaced it with one in which organisms and environments were totally separated". "The fundamental dichotomy of evolutionary theory", in the words of Levins and Lewontin (1985, p. 52), became "that of organism and environment", and in this way, the core problems of Cartesian metaphysics were effectively spread from the question of the nature of human minds and their relation to the world to life as a whole.

## CLOSED-CIRCLE THEORY VS. EVOLUTIONARY EPISTEMOLOGY

Post-Cartesian theories of psychology or epistemology can be generally located in one of two competing paradigms — the work of the later Wittgenstein, Kuhn and others being exemplars of the first and the work of Popper, Campbell, Lorenz and others being exemplars of the second (Munz, 1985, 1987). The proponents of the first, "closed-circle theorists", who have worn incommensurability and relativism almost as a badge of enlightenment, look to sociology or social psychology as the basis for meaning and intentionality, while evolutionary or natural selection epistemologists, proponents of the second, look to biology, or, more particularly, to Darwinian evolutionary theory as the ground for the epistemic dimension.

### *Closed-circle theory and the sociology of knowledge*

Closed-circle theory finds roots in the functionalism of Durkheim and Malinowski, and the "sociology of knowledge" of Mannheim. Earlier roots go back to Marx and Engels' work on ideology, and Spencer before. While the common thread to all these various ancestors was the idea that social ordering determines individual action, it should not be construed that all were closed-circle theorists in the extremized post-modern form of Wittgenstein and Kuhn (Swenson, 1997a).

Social systems, according to Durkheim (1895-1938), were said to have a reality outside the existence of individual humans that acts to determine their meaningful relations and intentional behavior. In explicit reaction to "psychologism", the idea that cultural systems are rational constructions of individual intentional agents, as well as the prevalent evolutionary views of history or culture, Malinowski held that human social or cultural systems were effectively closed circles where the parts all function to maintain the whole. Given that the circular relations of such a system were seen to refer back to themselves — that the function of the system is *to maintain itself* — they were said to exist *sui generis*. Everything is explained with respect to something else that happens internal to the circular relations of the system.

Wittgenstein further extremized this view by transposing it into a sociological version of the Cartesian circle. Rather than the circular relations constituting the self-referentiality of the human mind, Wittgenstein's circle was constituted through the intersubjective circular relations of humans within a cultural system. Meanings, said Wittgenstein, are formulated and stated in "language games" consisting of a set of rules that constitute closed circles of meanings. Because there is no individual language there can be no individual meanings, and because such systems are closed circles there can be no ostensive pointing or reference to anything outside the system (i.e. an objective "world"). What is more, because meaning is entirely relative to the rules of each system and thus meaning invariance is denied, such circles of meaning are incommensurable with respect to each other. Truth thus varies from one closed circle to the next, and can only be measured with respect to the rules or authority of a particular community.

In Kuhn's influential history and philosophy of science Wittgenstein's closed-circle language games were turned into paradigms, and the history of science the shift from one paradigm to another (scientific revolutions). Since reality is taken to be an ideal construction of human cognizers operating under particular paradigms, and since paradigms as closed circles are incommensurable with each other there is no progress in science or in Kuhn's view — without meaning invariance there is no way to make a comparison. In this view, Einstein's physics does not subsume or explain Newton's but rejects it. The post-modern structuralism of Foucault, Derrida, and the post-modern pragmatism of Rorty, which uses Foucault, in effect, to justify Wittgenstein (Munz, 1987), are all closed circle theories that share the common premises of the relativity of meaning to circularly closed systems, and the incommensurability of such systems with respect to each other and an external world. Closed-circle theory carries forward the anti-realist position of positivism, but in addition attacks its rationality.

### *Evolutionary epistemology: evolution as a knowledge acquisition process*

Evolutionary or natural selection epistemologists have a point of view almost directly opposite to that of the closed-circle theorists (e.g. see Callebaut &

Pinxten, 1987; Radnitzky & Bartley, 1987). Whereas closed-circle theorists such as Wittgenstein and Kuhn are arch anti-evolutionists, evolutionary epistemologists hold that knowledge is the product of evolution, and that evolution at its core is a progressive and continuous knowledge acquisition process, in Popper's words, "from amoeba to man" following from natural selection. Every living thing has knowledge in the expectations on which its intentional behavior depends, and this knowledge as the consequence of natural selection is true (hypothetically) since if it were not the living thing in question would be dead. Thus while true knowledge to the closed-circle theorist follows from cultural authority under a particular paradigm, to the evolutionary epistemologist it is determined with respect to the performance of an epistemic agent in the world. Scientific knowledge is seen to be continuous with evolution by natural selection since it too involves a trial and error process of selection through the proposal and refutation of falsifiable hypotheses (Campbell, 1987).

### *Both approaches are Cartesian at their cores*

#### Closed-circle theory is the Cartesian circle regressed

Although closed-circle theory is often given as a kind of enlightened alternative to modernism, it is itself modernism carried to a certain post-Humean, post-Kantian, extremized conclusion — the Cartesian core is still there only wrapped in sociological packaging. More precisely, it is the Cartesian circle regressed from the individual to the cultural level. Regressed because the original epistemic problem of the Cartesian circle still remains, and by extending the idea to culture, a second one is added. Regressive moves of this kind are defining symptoms of what Lakatos (1970) has called "degenerative problem shifts", and they are inherent to dualist schemes. The various problems of closed-circle theory are of four main kinds which are all related.

1. *The premises of closed-circle theory make it anti-evolutionary by definition, and it thus offers no account (nor cares to) of evolutionary dynamics, in particular, the directed and expansive nature of the epistemic or psychological dimension in evolution.* Closed-circle theory is anti-evolutionary in two ways. The first is that because closed circles are incommensurable with each other there is no way to assert that they are part of any evolutionary process — no continuity over the discontinuity, and thus no ground to assert an ordinal measure with respect to the direction of time. From this perspective there is a deep incoherence in closed-circle theory as a history of science because it must rely implicitly on principles to state its position that it theoretically denies. Kuhn, for example, relies on a historical comparison of paradigms to claim that such paradigms are incomparable. In addition, while the history of science for Kuhn is taken to be constituted by paradigm shifts there is no principled way to address when or why such transformations should occur, or that they should appear in any particular order, e.g. Einstein's theory could just as well have preceded Newton's, the

theory of oxygen that of phlogiston, or the theory of heat that of the caloric.

The second way that closed-circle theory is anti-evolutionary is by grounding meaning in the intersubjective relations of humans. The consequence is similar to the consequence of Descartes' view of perception as a rational process which, when coupled with the further claim that only humans are capable of rational processes, took the entire psychological dimension away from the rest of life. Closed circle theory, while abandoning "the thing in itself", is a further extremization of the anthropocentric "revolution" of Kant which has the epistemic acts of humans, in effect, dictating reality to the rest of the world, which in the case of closed-circle theory is ideally created anew, and entirely at random, without rhyme or reason, with each new paradigm.

2. *The formal causality postulated at the core of closed-circle ontology constitutes an illegitimate teleological principle with respect to accepted physical and biological principles.* By making the fundamental reality the circularly defined cultural system, closed-circle theory substitutes "formal cause" (the form or shape of a thing, in this case the circular relations) for the usual efficient cause that constitutes the notion of causality in modern science. The components are determined by the dynamic functional ordering of the whole rather than the other way around.

But here arises the problem that has discredited virtually every one of closed-circle theory's functionalist ancestor's before it (see Turner & Maryanski, 1979) — by the most widely accepted principles of physics and biology, the end-directed behavior it invokes entails an illegitimate teleological principle. Downward causality, or formal cause, was removed from modern science, along with final cause, at its origins. Biology, on the one hand, rejects such causality because functional behavior is taken to follow from natural selection, and the functional ordering of closed-circle systems, which are populations of one cannot follow from natural selection. Physics, on the other hand, has traditionally rejected such spontaneous ordering because the world, on the received view of the second law of thermodynamics, has been taken to be collapsing to disorder.

3. *The intersubjectivity at the core of closed-circle theory begs the old Cartesian questions and doubles the problem.* The Cartesian circle follows logically from the first postulate of incommensurability and the claim that perception is by the mind of the mind. What I know indubitably, said Descartes, in his famous *cogito ergo sum*, is my own active self-reflective mind. Claims about knowledge of an outside or objective world, on this view, are impossible, and claims for the existence of such a world, therefore, effectively irrelevant (since two incommensurable things have no causal efficacy with respect to one another), and on parsimony simply unenlightened superstition. By taking the idea of the self-reflective Cartesian circle and invoking it at the cultural level instantiated by the intersubjective relations of individual humans, closed-circle theory begs the original Cartesian questions and doubles the problem.

Briefly put, meanings for the closed circle theorist exist in the persistent and invariant relations constituted by the intersubjective relations that define the closed circle. To each individual, however, this requires persistent and invariant relations with an outside world, and this requires a non-Cartesian theory of perception. In short, intersubjectivity requires breaking the Cartesian circle since the individual mind is no longer simply perceiving itself, but something external in relation to which it comes to be determined or defined, and this requires a commensurability between knower and known which undercuts the ground of closed-circle theory — once the Cartesian circle is thus broken there is no longer any principled basis for it.

4. *Closed-circle theory simply supports the status quo, a dubious distinction in a rapidly changing world.* Closed-circle theory is sometimes taken to be enlightened because in its denial of a measure for the ordinal comparison of cultures it fosters an egalitarian view, but the idea of closed-system theory that truth is determined by the authority of a community carries a severe ideological price tag of its own since it makes no distinction between ways this epistemic authority is established. When taken to its logical conclusion there is no way to discriminate between truth obtained by scientific methods, by religious revelation, or authority achieved at gun point. Meaning and truth are simply determined by those in power, and given the incommensurability of various power structures operating under particular paradigms there is no way to compare or make a judgement about one with respect to another — pragmatism, conventionalism, instrumentalism, and so on, under this view can only serve, by definition, to reinforce hegemony, or the status quo, whatever it is.

## The problem with evolutionary epistemology is Darwinian evolutionary theory

The problem with evolutionary epistemology is that it relies on Darwinian evolutionary theory, but evolutionary theory reduced to Darwinism can never provide an account of the epistemic dimension, either the active intentional striving of living things or the meaningful relations it entails (Swenson, 1997a, 1997c). The four distinct, but related, reasons for this, all follow directly from its Cartesian foundations:

1. *The situational logic of natural selection, and hence Darwinism as a theory of evolution assumes the psychological or active epistemic dimension to begin with.* The core concept of Darwinian theory is natural selection (Depew & Weber, 1995). Evolution, according to Darwinism, follows from natural selection and natural selection is entailed by a situational logic (Popper, 1985) — if certain conditions hold then natural selection will necessarily follow. These conditions are heritable variation, finite resources and the fecundity principle, a biological extremum principle that captures the active striving of living things. Natural selection, said Darwin (1959/1937, p. 152), follows from a population of replicating or reproducing entities with variation "striving to seize on every unoccupied or less well occupied space in the economy of nature". Because "every organic being", he said (Darwin, 1959/1937, p. 266), is "striving its utmost to increase, there is therefore the strongest possible power tending to make each site support as much life as possible". Paraphrasing Darwin, in Schweber's (1985, p. 38) words, this says that nature acts to "maximize the

amount of life per unit area" given the constraints. Because natural selection is thus seen as a consequence of the fecundity principle, and because the fecundity principle assumes the active intentional dynamics or psychological or epistemic dimension of living things, an explication of the psychological dimension is beyond the reach of natural selection, and hence, by definition Darwinian theory.

2. *The claim that the growth of knowledge is a progressive evolutionary process is an assertion that can neither be made nor explained from the ground of Darwinian theory because the relevant observable (fitness) is relativized to members of breeding populations.* Evolutionary epistemology makes the claim that the growth of knowledge is continuous from "amoeba to man", and the measure of the knowledge a living thing possesses is its fitness. But fitness, on the Darwinian view, and thus knowledge, is relativized to members of a breeding population (species). Thus a zebra who can run faster than another zebra, avoid predators better, and thereby produce more offspring is more fit, and can be said to possess more evolutionary knowledge, than a zebra that is slower, but a zebra cannot be compared on the same basis to a mouse, or to an amoeba. Mice can only be judged more or less fit with respect to other mice, zebras with respect to other zebras, and amoebas with respect to other amoebas, and this makes fitness an incommensurable observable with respect to any assertions about evolution writ large.

3. *Given the second postulate of incommensurability assumed by Darwinian theory there are no grounds within the theory from which epistemic or meaningful relations between living things and their environments can take place.* The fecundity principle on which evolution on the Darwinian view crucially depends assumes the active intentional dynamics of living things — it assumes the meaningful determination of the behavior of living things with respect to their intentional ends. Given the second postulate of incommensurability built into the foundations of Darwinian theory, however — the rejection by Darwinism that what is inside and what is outside are part of the same whole system (Lewontin, 1992), there is no principled basis for meaningful relations to take place. Such a basis cannot be given by a theory like Darwinism that holds biology and physics or living things and their environments to be incommensurable.

4. *Darwinism has no account of the insensitivity to initial conditions (like consequents from unlike antecedents) required to account for the reliability of intentional dynamics or the evolutionary record writ large.* On the mechanical view of the world causality is reduced almost entirely to efficient cause (like antecedents produce like consequents), but the intentional dynamics of living things require like consequents from unlike antecedents. In short, to use the felicitous terms of Dyke (1997), they must be "end-specific" and not "start specific". The dynamics of living things require giving a fundamental ontological status to "formal causes", in Aristotle's terms, that function nomologically at a macroscopic level to attract and entrain micro-components towards determinate macroscopic ends regardless of differences (within tolerance) of microscopic starting conditions. Among other things, this goes to the issues of multiple realizability, downward causation, and the fact that forms in nature, including those considered as intentional dynamics "fall

out" at critical thresholds of dimensionless ratios. Darwinian theory, based as it is on efficient cause, continuous change, and the idea, in effect, that "anything goes" cannot address this fundamental dynamic.

5. *Darwinism cannot address cultural evolution or evolution of life as a single process at the planetary level because such systems evolve as populations of one, and natural selection can only 'explain' the results following from a competing population of many.* In contrast to the closed-circle theorists who take scientific knowledge to be irrationally determined under a paradigm, evolutionary epistemology takes the production of scientific knowledge to be determined by a process of rational, critical selection. But cultural systems are circularly causal, and the production of human knowledge is culturally determined — cultural systems are defined by world views or paradigms and what is accepted as meaningful pursuits or intentions, including the pursuit of scientific questions (and thus answers) are typically those that support the underlying paradigm. What is more, evolution itself at the planetary level is a single global circularly causal system on which the ordinary objects of Darwinian study as well as cultural systems depend (e.g. for a steady and reliable supply of oxygen). Darwinism cannot address the circular causality of cultural systems or life at the planetary level on which all other terrestrial evolutionary products depend because such systems evolve as populations of one and natural selection only works on a population of many (Dawkins, 1982; Maynard Smith, 1988; Swenson, 1991a).

## AUTOCATAKINESIS, THE EPISTEMIC DIMENSION, AND EVOLUTION AS SELF-ORGANIZATION

### *Return to cogito*

Descartes had two important things right. The first was his admonition to challenge authority (what are closed-circle theorists to do!?), and the second was the general idea of his *cogito ergo sum*, his assertion that what each of us knows indubitably (viz., what certainly exists) is the fact of our own epistemic experience. What Descartes had wrong after that, however, by asserting the first postulate of incommensurability (the dualism of self vs. other, knower vs. known, or psychology vs. physics), in a sense, was everything. Being more precise, of course, Descartes did not exactly say that "what I know indubitably is the fact of my own epistemic experience", what he said was "what I know exists indubitably is the independent 'self' or 'thinking I' ('mind')", in short, the Cartesian circle, and this is where Descartes made his major error because such an independent self or mind is just what none of us knows. Whether a consequence of individual perceptions, actions, feelings, thoughts, imagination or any form of experience each of us only experiences our self in relation to that which we are not — no self without not-self, no knower without known, no subjective without objective. Even the conception is unimaginable. In short, the Cartesian circle is a myth. Self-reference, in the epistemic experience, is defined by the relation of the self to that which it is not.

What is more, the persistence or invariant properties that define the relation means there is a conservation over the relation, a third thing known that is neither self nor other that remains invariant over the two, and there are two other fundamental properties entailed by the epistemic experience (the "epistemic given") too. The first is the circular relations implied by self-reference, and the second is time-asymmetry or irreversibility. The circular relations defining self-reference take place through a one-way flow of time. Persistence of the defining relations means conservation through process — the conservation must flow for a self-other relation to persist. These fundamental properties, a defining relation between self and other, the circularity constituting the relation, a conservation over the relation, and one-way flow of the conservation provide a kind of minimal set of world properties or ontological conditions entailed by the epistemic experience. Figure 1 shows a schematic of this minimal ontology — (a) shows the conservation, that which is neither self nor other, and out of whose flow the self-other relation is constituted, and (b) shows the self-other relation circularly constituted in the directional flow.

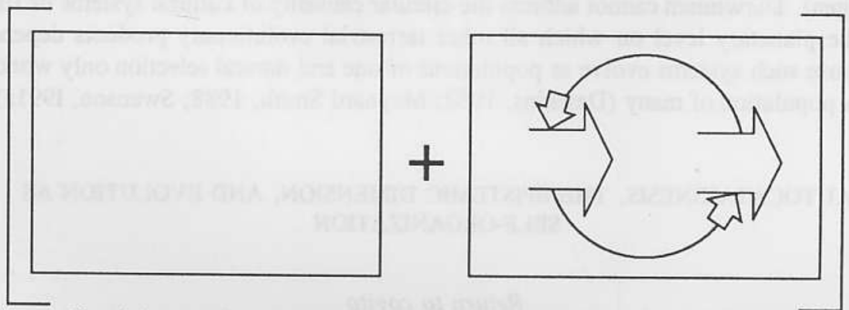


Figure 1. The minimal ontology. From Swenson, 1997c, p. 68, copyright 1997 Lawrence Erlbaum Ass., Inc., reprinted by permission.

### *Autocatakinetics*

The non-Cartesian conjunction shown in Figure 1 (call it the "embedded circle") provides the basis for understanding the commensurability between physics, psychology and biology where it becomes possible to subsume what is right about closed-circle theory and evolutionary epistemology, while getting rid of the Cartesian ghost and the resulting degenerative problemshift to give a principled account of the emergence and evolution of meaning and intentionality or the epistemic dimension. Epistemic agents, following Figure 1, can be seen to be members of a class of systems called "autocatakinetic", a term referring to self-organizing or spontaneously ordered systems.[1] Autocatakinetic systems are flow structures that by pulling resources into themselves maintain their identities through the flux or motion of their components. In other words, invariance at one level, the form of the thing, is constituted by change or motion at the component level.

The root of the idea goes back at least to Heraclitus (536 B.C.) who characterized the world as a process of continual flow, and its objects as constituted by a generalized metabolism or combustion. Fire, as Aristotle (1947, p. 182) wrote centuries later in *De Anima*, stressing the active agency and generalized metabolism of such systems, "alone of the primary elements (earth, water, air, and fire) is observed to feed and increase itself". In this century, von Bertalanffy (e.g. 1952) developed these ideas under the name of "open systems", and Prigogine (e.g. 1978) under the heading of "dissipative structures". An autocatakinetic system is defined as one that maintains its "self" as an entity constituted by, and empirically traceable to, a set of nonlinear (circularly causal) relations through the dissipation or breakdown of field (environmental) potentials (or resources) in the continuous coordinated motion of its components (from *auto-* "self" + *cata-* "down" + *kinetic*, "of the motion of material bodies and the forces and energy associated therewith" from *kinein*, "to cause to move") (Swenson, 1991a). From this definition other examples of autocatakinetic systems, in addition to flames, can be seen to include dust devils, hurricanes, tornadoes, and all the entities typically taken to be living, including human cultural systems (e.g. tribes, chiefdoms, nation states and empires), and perhaps most importantly, the planetary system as a whole of which all the rest are component productions. Figure 2 shows a generalized drawing of an autocatakinetic system.

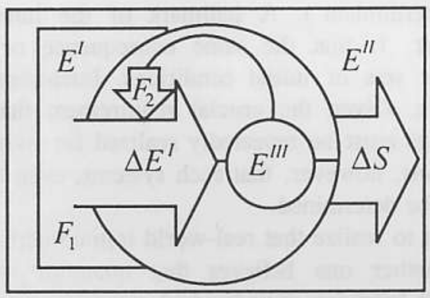



Figure 2. A generalized autocatakinetic system. $E^{I}$ and $E^{II}$ indicate a source and a sink with the difference between them constituting a field potential with a thermodynamic force $F_1$ (a force being the gradient of a potential) the magnitude of which is a measure of the difference between them. $\Delta E^{I}$ is the energy flow at the input, the drain on the potential which is transformed into entropy production $\Delta S$ at the output. $E^{III}$ is the internal potential carried in the circular relations that define the system by virtue of its distance from equilibrium that acts back to amplify or maintain input during growth or non-growth phases respectively with an internal force $F_2$. From Swenson, 1991a, p. 45, copyright 1991 Intersystems Publications, adapted by permission.

### *Kinds of causality, autocatakinesis, and non-Cartesian circles*

Part of mechanistic or Cartesian hegemony is the idea that nomological description means reduction to efficient cause, but to accept this notion is simply to proceed from the view of "normal science", in Kuhn's phrase, *within* the Cartesian paradigm, and intentional dynamics, and the minimal ontology it entails as expressed in autocatakinesis are not reachable from the Cartesian core. The Aristotelian causal system (in various versions), the system mechanistic theory replaced asserted a multiple causal framework with four distinct and kinds of causes of which efficient cause was just one. The three other kinds were material, formal, and final. Such a four-cause framework, suitably brought up to date is remarkably useful in understanding the dynamics of self-organizing systems.[2] In particular, the removal of formal and final causes, the removal of all enddirectedness from the physical world was a crucial part of the dead mechanical world view that gained ascendancy with modern science. But the world, as Aristotle recognized, is inherently active and end-directed and if the epistemic dimension is ever to be understood it is precisely this aspect of the world that must be grasped. The epistemic dimension of things, their shape, development, and intentional behavior, is not, and, as we shall see, *cannot* be micro-determined (viz., determined by efficient cause), but arise and are determined nomologically nevertheless.

Insensitivity to initial conditions, downward causation, or macrodeterminacy

Central to the mechanistic conception is that like antecedents produce like consequents — that macroscopic dynamics are micro-determined, and that to change the micro-conditions produces a change in the macro-conditions that follows deterministically from the equations of motion. If one knows the coordinates of the components at some time then, in principle, one knows all future and past states ("Laplacian determinism"). A hallmark of the intentional dynamics of living things, however, is that the same consequence or end state typically follows from different sets of initial conditions. Intentional dynamics are not Laplacian deterministic. Given the crucial requirement that precise behavioral patterns of living things must be repeatedly realized for living things to function or survive, surely means, however, that such systems, even though not Laplacian determined, must still be determined.

In fact, it is striking to realize that real-world initial micro-conditions are never the same twice. Whether one believes that quantum states are objectively probable (meaning that behavior of individual events is not predictable although the average behavior is), or the older notion that stochasticity is simply a matter of human ignorance, the micro-conditions at one time will, for all practical purposes, never be the same as at some other time. If Laplacian determinism were true then the repetition of forms not only of behavior, but of behaving things themselves would be inconceivable.[3] The real-world dynamics of autocatakinetic systems of which intentional ones are a kind show a remarkable *insensitivity to initial conditions*. They produce the same end states from different initial conditions. The significance of this remarkable fact, first used by Driesch against mechanism and in support of vitalism, recognized in a non-vitalistic form by von Bertalanffy under the name of "equifinality", and by Weiss under the name of macro-determinacy, has been repeatedly stressed by developmentally minded evolutionary theorists (e.g. see Salthe, 1994; Swenson, 1991a, 1992).[4]

Figure 3 shows two time slices from the Bénard fluid experiment, an exemplar of spontaneous order production or self-organization in a simple physical system. The left-hand photograph shows the disordered regime and the right-hand one shows the spontaneous production of order that occurs when the energy gradient or potential between source and sink is increased beyond a critical minimal threshold and the fluid spontaneously fills with Bénard "cells". The cells in the photograph are seen to be of variable size and shape. As time continues, however, a spontaneous process of selection occurs that includes the subsumption of smaller cells by larger ones, the competitive exclusion of smaller cells by larger ones, and the spontaneous division of larger cells to smaller ones (e.g. see Swenson, 1989a, 1989b, 1992, and in press, for the time series). The end result is a regular array of hexagonal cells of uniform size and shape. The variability that is seen at the beginning of the process is a consequence of the fact that order production is stochastically seeded.

In particular, in the disordered regime the dynamics are characterized by random collisions between micro-components which constitute fluctuations around an average state. When the critical threshold is crossed spontaneous order is seeded by any fluctuation anywhere in the fluid that is of a minimal amplitude. Since the location and actual amplitude of such fluctuations is stochastically determined the cells will form at different places in the fluid and grow at different rates every time the experiment is done. Seconds after the critical threshold is crossed the fluid thus fills with cells of variable size, but each and every time the experiment is run the variability in the size and shape is progressively eliminated by a process of selection to produce a final state of hexagonal cells.

In a decidedly non-Laplacian fashion, *unlike micro-antecedents lead to like macroscopic consequences*. Here we see a process of "blind variation" in the stochasticity of the micro-components in the disordered regime and a lawful process of selection leading to a macro-determinate result. Random initial conditions at the micro-level do not mean that the evolution of the system is random or undetermined.

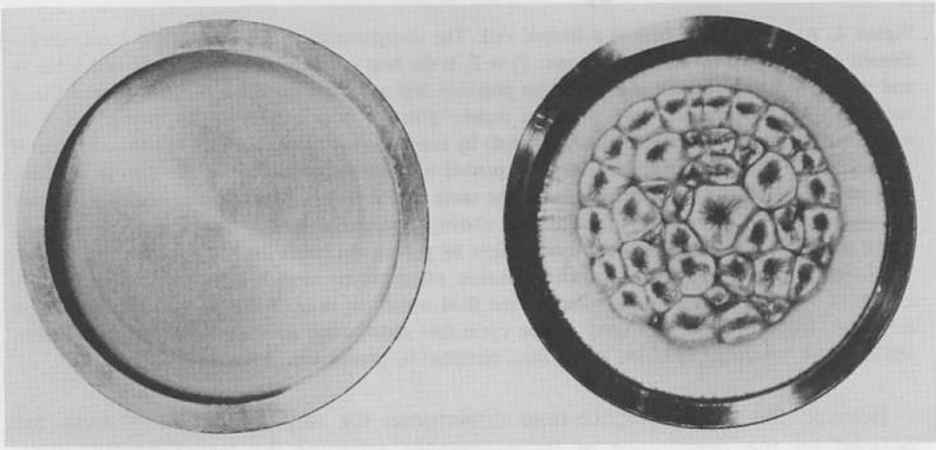


Figure 3. Bénard cells. Two time slices from the Bénard experiment. The first time slice (left) shows the homogeneous or disordered "Boltzmann regime" where entropy is produced by heat flow from the disordered collisions of the molecules (by conduction), and the second (right) shows entropy production in the ordered regime. Spontaneous order arises when the field potential is above a minimum critical threshold and stochastic microscopic fluctuations are amplified to macroscopic levels and hundreds of millions of molecules begin moving coherently together. From Swenson, 1989c, copyright 1989 Pergamon Press, reprinted by permission.

The Interplay of micro and macro and the expansion of space-time dimensions

The establishment of autocatakinesis or the origins of order is generic across scales. In each case it involves 1. stochasticity or "blind variation" at the micro-level that "seeds" order at the macro-level, 2. circular causality to amplify the microscopic seeding and constitute the order at the macro-level, and 3. a source-sink gradient above some minimal critical level sufficient to pump up or fill out the new dimensions of space-time spontaneous ordering entails. These principles can be seen at work in the Bénard experiment with a more detailed look. Figure 4 shows a schematic of the pattern of flow that defines the autocatakinesis of a single Bénard cell.

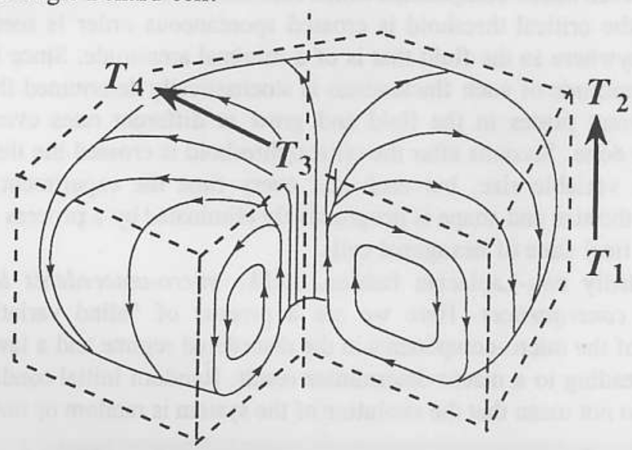



Figure 4. Autocatakinetic flow in a Bénard cell. The autocatakinetic flow of the fluid constituting a Bénard cell is shown by the small arrows. $T_1 \rightarrow T_2$ is the heat gradient between the heat source below and the cool sink above that constitutes the potential that motivates the flow. Because density varies inversely with temperature there is also a density gradient from bottom to top giving groups of molecules ("parcels") that are displaced upwards by stochastic collisions and upward buoyant force. If the potential is above the minimum threshold parcels will move upward a faster rate than their excess heat can be dissipated to their surrounds. At the same time such an upward flow of heat will increase the temperature of the upper surface directly above it creating a surface tension gradient $T_3 \rightarrow T_4$ which will act to further amplify the upward flow by pulling the hotter fluid to the cooler surrounds. The upward displacement of fluid creates a vacuum effect pulling more heated fluid from the bottom in behind it which in turns makes room for the fluid which has been cooled by its movement across the top to fall, be heated, and carry on the cycle thus establishing autocatakinesis. From Swenson, 1997a, p. 24, copyright 1997 JAI Press, Inc., reprinted by permission.

Because the intrinsic space-time dimensions for any system or process are defined by the persistence of its component relations the transformation from disorder to order increases its dimensions dramatically. In the ordered regime of the Bénard example the intrinsic dimensions are of the order of seconds and centimeters — it takes the fluid some seconds to make an autocatakinetic cycle between source and sink, and the distance covered, or the dimensions of a single cell, is in numbers of centimeters. This is in stark contrast to the disordered regime where the intrinsic spacetime dimensions are defined by mean free path distances and relaxation times (the distances and times between collisions) and are on the order of $10^{-8}$ centimeters and $10^{-15}$ seconds.

The relation between micro and macro in the filling of higher-ordered dimensions of spacetimes follows from the amplification of a micro-stochasticity to macroscopic proportions by macroscopic feedback relations, and the way macro-motion works circularly to determine micro-motion by spontaneously selecting microscopic degrees of freedom, by entraining or pulling micro-components into its formation and maintenance, is clearly seen in Figure 4. Here we see the dynamics of the minimal ontology at work, the origin and persistence of non-Cartesian circles and their inextricable dynamical relation to their environments, but what is the nomological basis for such spontaneous ordering?

## THE LAW OF MAXIMUM ENTROPY PRODUCTION OR WHY THE WORLD IS IN THE ORDER PRODUCTION BUSINESS

### *The laws of thermodynamics are special laws of physics*

To say something is conserved or remains the same over certain transformations is to describe a symmetry, and to say that there is a one-way flow of something is to describe a broken symmetry. From this we see that these two first principles of the epistemic dimension given in the conjunction shown in Figure 1 are symmetry principles. Of great interest is the fact that they are also statements, in very profound form, of the first and second laws of thermodynamics. This underscores the point that the first and second laws of thermodynamics are not ordinary laws of physics. Because the first law, the law of energy conservation, in effect, unifies all real-world processes, it is thus a law on which all other laws depend. In more technical terms, it expresses the time-translation symmetry of the laws of physics themselves — there could be no laws, no invariances, no persistences or ongoing relations without time-translation symmetry, without a conserved quantity underlying the change. The second law not only governs the ordinary laws of physics, but the first law as well. If the first law expresses the underlying symmetry principle of the natural world (that which remains the same) the second law expresses the broken symmetry (that which universally changes). It is with the second law that end-directedness, and time itself, the ordinary experience of then and now, of the flow of things, is given nomological grounding.

### The classical statements of the first and second laws

Following the work of Davy and Rumford, the first law was first formulated by Mayer, then Joule, and later Helmholtz in the first half of the nineteenth century with various demonstrations of the equivalence of heat and other forms of energy. Figure 5 shows the experiment devised by Joule. The law was completed in this century with Einstein's demonstration that matter is also a form of energy.

The first law says that (a) all real-world processes consist of transformations of one form of energy into another (e.g. mechanical, chemical, or electrical energy or energy in the form of heat), and that (b) the total amount of energy in all real-world transformations always remains the same or is conserved (energy is neither created nor destroyed).

The first law was not fully understood until the second law was formulated by Clausius and Thomson in the 1850's. Some twenty-five years earlier Carnot had observed that like the fall of a stream that turns a mill wheel, it was the "fall" of heat from higher to lower temperatures that motivated a steam engine. That this work showed an irreversible destruction of "motive force" or potential for producing change suggested to Clausius and Thomson that either the first law was false (energy was not conserved), or else energy was not the motive force for change. Recognizing that the active principle and the conserved quantity could not be the same they realized that there were two laws at work and showed their relation. Clausius coined the word "entropy" to refer to the dissipated potential, and the second law states that all natural processes proceed so as to maximize the entropy (or equivalently minimize or dissipate the potential), while energy, at the same time is entirely conserved. The balance equation of the second law, expressed as $\Delta S > 0$, says that in all real world processes entropy always increases.

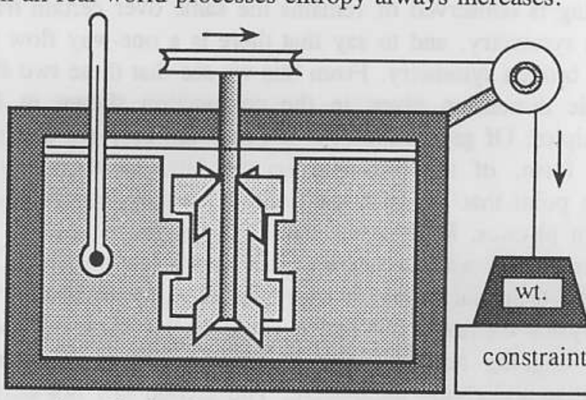



Figure 5. Joule's experiment showing the conservation of energy. When a constraint is removed, potential energy in the form of a suspended weight is converted into the mechanical or kinetic energy of a moving paddle wheel in an energy-tight container of water heating the water by an amount equal to the amount of potential energy lost by the falling weight. From Swenson, 1997a, p. 31, copyright 1997 JAI Press, Inc., reprinted by permission.

The second law provides the nomological bases for understanding the directed flow entailed by the minimal ontology. The crucial role of this broken symmetry in epistemic processes can be further grasped by returning to the experiment of Joule — although designed to show the first law it, and every other experiment designed to demonstrate the first law (e.g. Mayer and Helmholtz), demonstrated the second law as well. The act of turning the paddle wheel by the fall of the weight, and the measuring of the conservation (the energy) is an irreversible act — the measurement or epistemic act can only take place through or in the flow.

The second law as a law of disorder

The active nature of the second law presented a profound blow to the mechanical world view which Boltzmann attempted to save by reducing it to the stochastic collisions of mechanical particles — to a law of probability. Modeling the gas molecules of a gas in a box as colliding billiard balls, Maxwell had shown that non-equilibrium velocity distributions (groups of molecules moving at the same speed and in the same direction) would become increasingly disordered with each collision leading to a final state of macroscopic uniformity and maximum microscopic disorder. Boltzmann recognized this state as the state of maximum entropy (where the macroscopic uniformity corresponds to the obliteration of all field potentials). Given this, he argued, the second law was simply the result of the fact that in a world of mechanically colliding particles disordered states are the most probable. There are so many more possible disordered states than ordered ones that a system will almost always be found either in the state of maximum disorder — the macro-state with the greatest number of accessible micro-states such as a gas in a box at equilibrium — or moving towards it. A dynamically ordered state, one with molecules moving "at the same speed and in the same direction" said Boltzmann (1886/1974, p. 20), "is the most improbable case conceivable (...) an infinitely improbable configuration of energy".

Although Boltzmann himself acknowledged that his hypothesis of the second law had only been demonstrated for the case of a gas in a box near equilibrium, the science of his time (and up until quite recently) was dominated by linear, near-equilibrium or equilibrium thinking, and his hypothesis became widely accepted, and the second law came to be seen as a law of disorder. But the world is not a linear, near equilibrium system like a gas in a box, but is instead nonlinear and far-from-equilibrium, and the second law is not reducible to a stochastic collision function. As the next section outlines, rather than being infinitely improbable, a spontaneous ordering can now be seen as the expected consequence of natural law.

*The law of maximum entropy production*

A nomological basis for the world as active, and end-directed came with the recognition of the second law, but it did not seem to be the right kind of end-directedness for biology and psychology. Particularly with Boltzmann's interpretation, as Fisher, one of the founders of neo-Darwinism, noted, the end-directedness of the second law appeared to run directly opposite to the active, end-directedness of living things the fecundity principle and the intentional dynamics it entails has life producing as much order as it can. The problem was partly put aside in the middle of this century when von Bertalanffy (e.g. 1952, p. 145) showed that "spontaneous order (...) can appear in [open] systems" (systems with energy flows running through them) by virtue of their ability to build their order by dissipating potentials in their environments. Along the same lines, pointing to the balance equation of the second law, Schrödinger (1945) popularized the idea of living things as a streams of order which like flames are permitted to exist away from equilibrium because they feed on "negentropy" (potentials) in their environments. These ideas were further popularized by Prigogine (e.g. 1978).

Schrödinger's point was that as long as living things like flames (and all autocatakinetic systems) produce entropy (or minimize potentials) at a sufficient rate to compensate for their own internal ordering (their ordered persistence away from equilibrium) then the balance equation of the second law would not be violated. Order on the von Bertalanffy-Schrödinger-Prigogine view *can* arise spontaneously, and living things, on this view are thus *permitted* to exist, as it became popular to say, as long as they "pay their entropy debt". This worked for the classical statement of the second law per Clausius and Thomson, but on Boltzmann's view such "debt payers" were still infinitely improbable. Living things, and *a fortiori* evolution as a planetary process as a whole, were still infinitely improbable states struggling against the laws of physics — the urgency towards existence captured in the fecundity principle and the intentional dynamics it entails and in planetary evolution as a whole were entirely anomalous on this view with respect to universal law. What is more, as seen from the discussion of the Bénard experiment, simple physical systems also falsify Boltzmann's hypothesis. Order is seen to arise, not infinitely improbably, but with a probability of one, that is, whenever, and as soon as it gets the chance. The nomological basis for this opportunistic ordering was still a mystery.

## Return to space-time relations, order production, and the balance equation of the second law

A return to the balance equation of the second law provides the first clue towards solving the puzzle. As discussed above and illustrated with Figure 4, transformations from disorder to order dramatically increase the space-time dimensions of a system. What von Bertalanffy and Schrödinger emphasized was that as long as an autocatakinetic system produces entropy fast enough to compensate for its development and maintenance away from equilibrium (its own internal entropy reduction or increase in space-time dimensions) it is permitted to exist. Ordered flow, in other words, to come into being or exist must function to increase the rate of entropy production of the system plus environment — must pull in sufficient resources and dissipate them — to satisfy the balance equation of the second law. This makes an important point implicitly that now will be stated explicitly: *Ordered flow must be more efficient at dissipating potentials than disordered flow* (Figure 4 shows exactly how this works in a simple physical system), and this brings us to the final piece in the puzzle.

## The law of maximum entropy production

The crucial final piece to the puzzle that provides the nomological basis for dissolving the postulates of incommensurability between physics and psychology and physics and biology — between thermodynamics and evolution — is the answer to a question that classical thermodynamics never asked. The classical statement of the second law says that entropy will be maximized, or potentials minimized, but it does not ask or answer the question of which out of available paths a system will take to accomplish this end. The answer to the question is that *the system will select the path or assembly of paths out of otherwise available paths that minimize the potential or maximize the entropy at the fastest rate given the constraints*. This is a statement of the *law of maximum entropy production* the physical selection principle that provides the nomological explanation, as will be seen below, for why the world is in the order production business (Swenson, 1988, 1991, 1992, 1997a, 1997d; Swenson & Turvey, 1991). Note that the law of maximum entropy production is in addition to the second law. The second law says only that entropy is maximized while the law of maximum entropy production recognizes that it is maximized (potentials minimized) at the fastest rate given the constraints. Like the active nature of the second law, the law of maximum entropy production is intuitively easy to grasp and empirically demonstrate.

Consider the case of the warm mountain cabin sitting in cold, snow-covered woods. The difference in temperature between the cabin and the woods constitutes a potential and the cabin-woods system as a consequence will produce flows of energy as heat from the cabin to the woods so as to minimize the potential. Suppose the house is tight and heat is flowing to the outside primarily by conduction through the walls. Imagine now opening a window or a door which amounts to removing a constraint on the rate of dissipation. What we know intuitively, and can confirm by experiment, is that whenever a constraint is removed and a new path or drain is provided that increases the rate at which the potential is minimized the system will seize the opportunity. In addition, since the opened window, for example, will not instantaneously drain all the potential some will still be allocated to conduction through the walls. Each path will drain all that it can, the fastest (in this case the open window) procuring the greatest amount with what is left going to the slower paths (in this case conduction through the walls). The point is that no matter what the specific conditions, or the number of paths or drains, the system will automatically select the assembly of paths from among those otherwise available so as to get the system to the final state, to minimize or drain the potential, at the fastest rate given the constraints. This is the essence of the law of maximum entropy production. What does this have to do with spontaneous ordering, with the filling of dimensions of space-time?

Given what has already been discussed above, the reader may have already leaped to the correct conclusion. If the world selects those dynamics that minimize potentials at the fastest rate given the constraints, and if ordered flow is more efficient at reducing potentials than disordered flow, then *the world will select order whenever it gets the chance — the world is in the order-production business because ordered flow produces entropy faster than disordered flow* (Swenson, 1988, 1991, 1992, 1997a, 1997d; Swenson & Turvey, 1991), and this means the world can be expected to produce as much order as it can, to expand space-time dimensions whenever it gets the chance. Autocatakinetic systems, in effect, are self-amplifying sinks that by pulling potentials or resources into their own self-production extend the space-time dimensions of the fields (system plus environment) from which they emerge and thereby increase the dissipative rate.

## INTENTIONAL DYNAMICS AND THE PHYSICAL BASIS FOR ABOUTNESS

The law of maximum entropy production and its relation to autocatakinesis provides the nomological basis for the commensurability between physics, biology, and psychology. Ecological psychologists (e.g. Gibson, 1979) have argued the necessity of a mutuality postulate, namely, the recognition that living things and their environments constitute single systems, as a prerequisite to understanding the epistemic dimension of living things, and the law of entropy production shows how this postulate directly follows from natural law (Swenson & Turvey, 1991). The active striving of living things is no longer seen as a struggle against the laws of physics, but a manifestation of them. The fecundity principle, along with the intentional dynamics it entails, is seen as a special case of the law of maximum entropy production where the substrate (material cause in Aristotle's terms) is replicative. The epistemic dimension rather than being incommensurable and improbable is instead the expected behavior of the world acting back on itself in its own becoming. This provides a principled ground for the minimal ontology, the conditions of existence of the epistemic experience itself, and for evolution itself as about something other than individual fitness, as an epistemic process, in particular the dynamical means for accessing new dimensions of space-time.

### *The orthogonality condition*

There is one property that is implied in the description of the minimal ontology, but it needs to be explicitly stated. Namely, that the directedness towards that characterizes intentional behavior is experienced only by the fact that it is directed differently than the one way flow through which it is distinguished. In the most immediate case, I know my self by invariance through change, and through this recognition comes the deep connection of the epistemic experience to the cosmic project of building space-time dimensions captured by the "orthogonality condition" referred to in the introduction. Summarizing and expanding briefly as follows: all end-directed systems act to minimize potentials, and intentional systems as end-directed systems are no exception, but not all end-directed systems are intentional.

In particular, there is a principled distinction to be made, for example, between rivers that flow down hills, heat that flows down temperature gradients and living things whose intentional dynamics entails moving up not down gradients, and who unlike rivers and heat that stop flowing, or tornadoes and dust devils (or Bénard cells) that fall apart or "die" when the local potentials are removed, become more active instead. Intentional dynamics are not determined by local potentials. Instead the intentionality of living things functions to permit them to constitute their autocatakinesis through the minimization of (to feed on) non-local potentials — to move, to grow, to act in such a way so as to, in effect, "skate across" local potentials to access non-local potentials discontinuously located in space-time — to move in directions different from or orthogonal to those determined by local potentials. This is the essence of the orthogonality condition, and it is easily seen to have progressively increased over evolutionary time providing an ordinal measure not only for the epistemic or psychological dimension but for evolution as a single planetary process. This in turn, coupled with the nomological basis for the orthogonality condition in the expansion of space-time dimensions underscores the point that evolution itself is an active epistemic process, and one that follows from natural law.

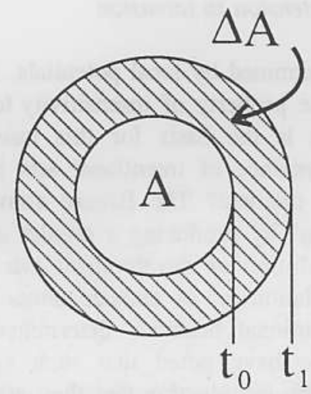
If we remember from the discussion above that the intrinsic space-time dimensions of a system are determined by the persistence of its component relations, we see at once the dramatic increase in accessible space-time dimensions as a consequence of the orthogonality condition, the ability of intentional systems to build their autocatakinesis off of non-local potentials.

*From extension to intension*

If intentional dynamics are not determined by local potentials, then how are they determined? Autocatakinesis has the property of insensitivity to initial conditions and macro-determinacy, but what is the basis for this insensitivity to initial conditions so crucial to the performance of intentional acts in a world that is microscopically different at every moment? The Bénard convection, which, in effect, "solves the packing problem" by producing a regular array of hexagonal cells during the course of its evolution or development can be understood in terms of the system's proximal relation to, or embeddedness within, a field of local potentials, but how is intentional behavior determined with respect to non-local or distal potentials? We have noted that such systems surely are determined, and we have said in the introduction that they are meaningfully so, or determined by information about, but how does one get from an otherwise meaningless world of extension or usual physical descriptions to a meaningful world of information about?

The principles of thermodynamics provide some immediate clues, namely, that one needs to look for macroscopic observables that capture invariant properties with relevance to intentional ends. In addition one would need to look for symmetry and broken symmetry, for observables that capture the nomological relation between persistence and change of the distal objects of intention with respect to their proximal or local space-time position with respect to the epistemic subject. The answer which follows from the two laws of thermodynamics has been most powerfully captured by Gibson's (1979/1986; Swenson & Turvey, 1991; Turvey & Shaw, in press) ecological concept of information. Living things are surrounded by ambient energy distributions (e.g. optical, mechanical, chemical) for which the mean energy content is extremely low relative to the energy used by living things from their on-board potentials to power their intentional acts. As a consequence of the fact that lawful or invariant relations exist between the macroscopic properties of such ambient energy distributions that are relevant to the prospective control of intentional ends, the former can specify or determine the latter.

Bacteria, for example, may move up a chemical gradient that lawfully specifies the source of their food, animals may use diffusion fields of diffusing volatiles that lawfully specify the sources of their intentional ends, and fields of mechanical waves and optical fields are used in similar ways. The ability to effect (or avoid) controlled collisions, for example, is a particularly crucial and widespread requirement for the intentional dynamics of many living things (e.g. soft collisions with little or no momentum exchange as in a bird landing on a branch, hard collisions with substantial momentum exchange as when a predator attacks a prey, and collision avoidance where the ends of an intentional agent require that it not collide with particular things). Information about such collisions is lawfully carried in the ambient energy field (the "optical flow field") that transforms itself as a living thing moves through it. Just as in the Bénard case where laws of form specify the origin of order, and its development, so too with intentional dynamics.




$$\tau = \left[\frac{\Delta A}{\Delta t}\,\frac{1}{A}\right]^{-1}$$

Figure 6. Information about is lawfully carried in ambient energy distributions. From Swenson, 1997a, p. 41, copyright 1997 JAI Press, Inc., reprinted by permission.

With respect to controlled collisions, the time-to-contact ($\tau$), as shown in Figure 6, is determined by the inverse of the relative rate of expansion of the optical flow field, and the information about whether a collision will be hard or soft is given by the time derivative or rate of change of the relative rate of expansion ($\dot{\tau}$) (Lee, 1980; Kim et al., 1993). For an intentional act requiring a soft collision, for example, such as a bird landing on a branch the rate of change must be $\dot{\tau} \geq -.5$. This single macroscopic variable nomologically carried in the optic flow precisely determines when a particular bird, for example, must open its wings to decelerate so that it does not, in effect, crash into a branch. This is again, a deceivingly simple idea with remarkable and profound consequences. It exposes the fact that, not only are the shapes and forms things assume nomologically determined by laws of form (e.g. that there is, within tolerance, a requisite ratio between flight muscle weight and body weight, or between wing span and body weight, or brain weight and body weight (e.g. Alexander, 1971)), but that information about or meaning carried in macroscopic flow variables nomologically determines the behavior of things towards their intentional ends (See Swenson, 1997a, 1997d; Swenson & Turvey, 1991 and Turvey & Shaw, 1995 for further discussion).

## CONCLUSION

The search for the nomological basis for the origin of intention and intension, the search for the origin and nature of the epistemic or psychological dimension, is a search for the nomological basis for end-directed ordering determined by meaning. Following Boltzmann's interpretation of the second law of thermodynamics it is "no surprise", in the words of Levins and Lewontin (1985, p. 19) "that evolutionists [came to] believe organic evolution to be the negation of physical evolution". Noting the opposite directions followed by physical and biological (and by implication, psychological) systems, Ronald Fisher (1930/1958, p. 39), one of the founders of neo-Darwinism, wrote that "entropy changes lead to a progressive disorganization of the physical world (...) while evolutionary changes [produce] progressively higher organization (...)" Konrad Lorenz (1973, p. 20), one of the founding fathers of evolutionary epistemology, wrote that the aspect of life "most in need of explanation, is that, in apparent contradiction to the laws of probability, it seems to develop from (...) the more probable to less probable, from systems of lower order to systems of higher order".

The law of maximum entropy production, coupled with the generic properties of autocatakinesis, and the fact that information about distal potentials is lawfully carried in the invariant properties of ambient energy flows, solves the problem of Fisher and Lorenz, and provides the ground for a nomological account of spontaneous epistemic ordering or intentional dynamics. The law of maximum entropy production says that potentials are minimized at the fastest rate given the constraints, and, following the balance equation of the second law, autocatakinetic or spontane-ously ordered systems work spontaneously to increase the rate. As a consequence, the world acts opportunistically to produce as much order as it can. The epistemic dimension, the urgency towards existence characterizing the intentional dynamics of living things expressed by the fecundity principle and the process of terrestrial evolution writ large is thus not only commensurable with universal first principles, but a direct manifestation of them. This view provides a principled basis for uniting living things and their environments, knower and known, or self and other as reciprocal parts of an active world acting back on itself in its own becoming.

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## NOTES

[1] The term draws the distinction between "real-world" law-based self-organizing systems and rule-based systems (e.g., those relating to automata theory, Boolean nets and various other connectionist models) which depend on rules programmed into them by human designers. All rule-based systems are ultimately internal productions of autocatakinetic systems, but the reverse is not true.

[2] For further discussion of the limitations of efficient cause and re-examination or reinterpretation of Aristotle's causal framework see Swenson, 1990, 1992, 1996 (on all four causes), Swenson & Turvey, 1991 (on final cause), and also Rosen, 1987; Salthe, 1985, 1994 (on all four causes) and Van de Vijver (all four causes), this volume.

[3] The failure to understand this crucial point, has led particularists or historicists (e.g. Gould, 1989) to argue that if one "rewound the tape of life on Earth" that, as a consequence of chance fluctuations ( "errors") of the microcomponents, the system would repeatedly branch off onto different trajectories with the result that evolution would be dramatically different every time — there would be an astronomically high number of possible states the system might assume, and thus the possibility of the repetition of similar trajectories such as those that would lead to "intelligent life" such as humans would also be astronomically improbable. But if the world were actually microdetermined in this way the world as we know it would not merely be improbable but impossible.

[4] See Depew (this volume) for some discussion of development and evolution.

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