Ecological philosophy: Vitalism versus physical-chemical explanations (MS No. 244)

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Synopsis

I trace a discursive trajectory from vitalism through organicism to historicism, justified by the fact that there is no formal difference between arbitrary acts and random events. Vitalism's discursive role was opposition to mechanicism, an opposition continuing today as a dialectic between historicism and determinism. By focusing on natural kinds and molar / statistical properties, physical-chemical discourse constructs a mechanistic understanding in the interests of determinism and predictability. Complexity involves a susceptibility to perturbation by historical accident since complex models of causality allow for perturbations from contingent fluctuations. Models of complexity using hierarchy theory reflect this susceptibility as well, but project a world that emerges from a physical-chemical base. Historicity emerges prominently in middle level, macroscopic systems, where ecology happens to be focused. In ecology pragmatic understanding is engendered by limiting the degrees of freedom used in constructing observables, and by using statistics. When taking change into account, this approach results in a developmental discourse. Determinism and historicity both continue to inhabit ecology today in dialectical opposition.

Keywords

causality, complexity, convergent evolution, determinism, development, Eltonian niche, equifinality, hierarchies, historical ecology, historicism, mechanicism, natural kinds, organicism, randomness, thermodynamics

From Vitalism to Historicism

This essay will involve a Whiggish reinterpretation of vitalism. Vitalism crystalized as an explicit biological philosophy in the Nineteenth Century when a crude mechanicism appeared to some to be implausible as a mode of understanding living systems. In our day its critique of mechanistic discourse has been replaced by organicism, which views biological phenomena as being emergent from material arrangements -- configurations and associated conformations -- at several levels of scale. (This view has been appropriated by most biologists only at the level of macromolecules.) Material arrangements in Nature generally are, at all scales, the products of historical contingency, and range from the likes of impediments to water flow in a drainage system to the arrangement of nucleic acid bases in DNA. Thus, vitality was replaced by organization, which embodies constraints that can be shown to devolve from historical contingency. For example, the neoDarwinian account of genetic arrangements spans random mutations and the coincidence of environmental changes supportive of those mutations -- it is a theory of chance from top to bottom, with representation of the results preserved at the molecular level. On the present account, then, the vitalism cum organicism versus mechanicism debate has implicitly been replaced by an historicist / mechanist dialectic. So we can construct a conceptual trajectory from vitalism through organicism to historicism. More particularly, organicism naturalized vitalism while historicism co-opts organism.

In support of the logic of this progression, I note that there is no formal way to differentiate a random event from an arbitrary action. To illustrate this, consider sequences of moves in chess games -- e.g., knight followed by pawn. Such moves are made after considered evaluation, but there are enough degrees of freedom left over so that the moves can be considered to be arbitrary (that is, creative) as well. When treated as ensembles over hundreds of games, such sequences (per, say, the twenty earliest moves), emerge as Poisson distributed -- as do the number of times certain common words appear per twenty words in a long poem, or the number of times a given note appears per bar of music in a classical movement. Randomness is an external understanding of collections of historically contingent events and arbitrary actions. Vital impulses would presumably be held to be arbitrary, while an historical event results from a collision of contingencies. These are just two sides of a discursive boundary -- the vital / intentional interpretation would be internalist, while the historical one is externalist. So the vitalist / intentional perspective can be viewed as having morphed to the historicist perspective, which science has been able to partially tame by way of statistics.

Natural Science and Mechanicism

It should be understood that mechanicism has been the medium of all physical-chemical explanations -- indeed of almost all scientific understandings of any kind. The mechanical in this respect can be characterized as the most completely specifiable (i.e., entirely constrained) arrangement attainable for any kind of system. Linguistically, the mechanical is modelled by the most fully explicit descriptions of such arrangements, and this is where science finally embodies it -- its explicit inscriptions refer by default to a mechanistic world. An alternative account of mechanicism is that it is a mode of fabrication requiring external assistance in joining preexisting smaller subunits (this being in contrast to self-organization involving self-assembly). This view entails a bottom-up ideology, and is where biology, for example, necessarily connects to physical-chemical discourse; biology can be taken to be a mode of regulating chemistry.

Since the social function of natural science has, since Roger Bacon, been to facilitate control -- or at least prediction -- of natural processes, this raised the need for a deterministic discourse whereby the natural world might be approached, in the spirit of Newton, as a kind of machine. So natural science has been inspired by the ideal of determinism. Spanning the turn of the Twentieth Century, logic was honed to predicate logic, which, through propositional calculus embraced mathematics, delivering a tool within which scientific observations might be mediated into inscriptions and texts reliably reflecting observable aspects of the world. The collection of all scientific models could be labeled Nature, an edifice built fundamentally upon accumulating physical-chemical knowledge.

Perhaps Nature's main distinction from the World is that it is logical, and, ideally, precise. We can represent Nature as a specification hierarchy, as in: {physical processes {chemical affinities {biological arrangements {socioeconomic ideologies}}}}, while understanding the subclasses here (called integrative levels) to have emerged sequentially during the expansive cooling of the Big Bang, each by refinement of the information in the more inclusive classes (lower integrative levels) containing them . That is, Nature is shown here as fundamentally built upon a physical-chemical basis. But, while chemistry thus gives rise to biology, it is important to realize that biology in turn locally integrates chemistry, and physics, under its own rules. As an example, we see that physical diffusion is harnessed and controlled in organisms by the architecture of circulatory systems. Here we have introduced a top-down element into our understanding. The corralling of water flow into drainage systems shows that this principle is found in vaguer form in the physical-chemical world as well. This example emphasizes nicely the role of history in regulating the physical-chemical realm.

This top-down principle is seen also in another hierarchical construction commonly implicit in much of science discourse -- the scalar hierarchy, as in: [Earth [biome [organism [cell [macromolecule]]]]]. Here the brackets signify wholes and parts (indeed, as in machines). In this concept information from each lower level helps to make possible the next higher by generating possibilities, which are regulated by conditions at the next higher level, so that forms and activities at each level result from a dialog between the levels bracketing it, giving rise to a triadic understanding that is simultaneously both bottom-up and top-down. Yet, here again, Nature is founded upon physics and chemistry, which make up the most encompassing, as well as the very smallest scale, levels.

Determinism and Development

Ecology has developed within the tradition of pragmatics-inspired determinism as well. While ecology traditionally studied functions of the environmental relations of organisms and their populations, each of the integrative levels in the above specification hierarchy could support an ecological interpretation, with ecology being defined very generally as the study of energy and matter flow relations. Ecology so understood is more a systems perspective than the study of particular objects and processes, most of which can be assimilated to it, including the competition and predation studies of population ecology, as well as the species-abundance and scaling understandings of macroecology, and the life history studies of evolutionary biology. Traditionally ecology studied the sources, flows and sinks of organismic and population activities in natural environments. Later, in the context of hierarchy theory (initially the superorganism concept), and inspired by developmental studies in other fields, organismic environments came to be conceived as large scale developing systems themselves. In this light it was discovered that transformations -- as very generally characterized by information theory and thermodynamics -- from immaturity to senescence are followed by ecosystems as well as by organisms, and by other dynamic (including abiotic) systems as well. This very general understanding (see more below) is at present being constructed by way of the strategy of confirmation, motivated by the need for prediction.

Development can be defined quite generally as predictable directional change, and any observations with results too easily perturbed by history to be plausibly constructible at least as statistical moments would not be included in a developmental account. On the other hand, any reliably repeatable changes allow the inference that they are entrained by the constitutive processes of a, therefore, putative developing system. Thus, the need for reliable knowledge of change generates developmental discourse. Among ecosystemic changes discovered to be developmental, for example, are the energy flow changes during ecological succession (to be presented below).

Useful Knowledge

In any systematic investigation we need to know what can be known with some reliability. In general, this would not include the particular results of local historical accidents. Ultimately what has been sought in any science of dynamic systems are equations that can, given observed values for some of the variables, be solved to predict system states and future stages under given initial and boundary conditions. In complex systems like ecosystems, including organisms, this has been an ideal only. An equation like this, could we have it, would contain constants whose values would be required to be inserted before the equation could be solved. These values would for the most part also be the results of historical accident, but some of them (as in the laws of nature and, of lesser scope, the laws of matter) would be more global in effect, while others, say, scaling laws for kinds of organisms based on their size / metabolic rate range, or the slopes of relationships like those between species richness and productivity in given biomes, are more typical of ecology. These values, and the relationships they inform, are viewed as stable, reliable attributes of some greater or lesser portion of Nature, and would be the sort of useful knowledge sought by natural science.

Historicism, viewed as delivering only a poverty of information -- meaning no usefully reliable information -- is as uncanny from the perspective of natural science as vitalism was to mechanists. The mysterious actions of vital forces can today be assimilated to the capricious results of historical contingency. In cases where many historically determined events can be considered to be repeats of a kind of event, they can to some extent be tamed for science by way of statistics.

The Example of Thermodynamics

Natural science has devised ways to deal with systems that cannot be modelled mechanistically. Thermodynamics is an example where only the global states of systems are predictable, thereby allowing investigation of systems whose local details would be buffeted by incomprehensible caprice. All material systems ever observed are susceptible to, e.g., spontaneous diffusion, wave front spreading, and temperature equilibration (that is to say, all sorts of scattering processes), and these can be prevented only by exerting energy in work to counter them. In these respects Nature acts like a statistician, treating heterogeneous details together as ensembles, and working implacably to scatter them as widely as possible -- a tendency known as the Second Law of thermodynamics. In ecology these phenomena have been constructed as resulting from the spontaneously irreversible process of energy gradient dissipation, the driving force of all dynamics. The desired deterministic calculations can in thermodynamics be done globally, moving upscale and ignoring the historically susceptible microsystemic details. Local vitalist / organicist / historicist phenomena, generating the kinetics of intricate energy flow pathways, can change without perturbing thermodynamic predictions, which are made upon an irreversibly developing, more encompassing macrosystem.

Now we need to note that the Second Law of thermodynamics rules only in thermodynamically isolated systems, those with no inputs of energy or matter -- quite unlike any system observed in nature by ecologists, or economists. The overall simplifying assumption is made that the Universe itself is the thermodynamically required isolated system, within which all actual open systems are found. So these latter are necessarily contextualized by the universal disequilibrium engendered by the Big Bang expansion. It seems logical to suppose that the Second Law was generated as a reaction to the universe's accelerated expansion in the Big Bang because of the cooling consequent upon this expansion, as follows. This universal cooling precipitated matter out of radiation, which, by evoking gravitation, enabled the subsequent formation of masses. Clumps of matter further afforded the selection of forms and organizations as sequential indications of the universe's ever increasing distance from thermodynamic equilibrium. All material entities are energy gradients, and their instability in the context of the Second Law has been constructed as the local requirement for positive entropy production as a concomitant of anything that happens. So, when exergy for work is derived from a dissipating energy gradient, generally more than the amount so utilized diffuses away as heat energy, on its way to the global energy sink in the interest of universal equilibration. All natural processes are consequently relatively energy inefficient, irreversibly dissipating more energy than the amount actually used to power work.

Dissipative Structures

Dynamical entities existing under nonequilibrium conditions are for these reasons dubbed dissipative structures. They range from, e.g., hurricanes, through drainage systems to organisms. If we examine repeatable changes during the existence of any kind of dissipative structure from its beginning to its natural termination (in ecology this would include ecological succession), we find quite generally: (1) an asymptotic increase in size, in information content, in orderliness (these three summed up under ascendency increase), and in gross energy throughput (power) entraining entropy production, which also results in increasing productivity on a diminishing returns pattern. A Fourth Law of thermodynamics has been proposed to represent these facts. (2) An initial increase up to a peak, followed by a gradual decrease, in mass specific power, these three phases (peak included) being constructed as the developmental stages, immaturity, maturity, and senescence. Dissipative systems thus exist as higher level developmental trajectories, (immature ->

mature -> senescent), ending naturally in failure followed by recycling. Repetition of this pattern in concatenated ecological successions in a given locale gave rise to the idea that stability in ecosystems is better viewed as a matter of resilience, with escape from stress by reverting to an earlier stage. Because of the development of senescence, it is often said that dissipative structures move during their existence toward a mass specific minimum entropy production regime, with few natural ones, however, getting anywhere near their possible minimum before getting recycled. (3) An increase in internal stability, involving stereotypic behavior which produces loss of flexibility, demonstrating as a consequence an increasing predictability of internally generated activity for an outside observer. (4) Consequent upon the increasing rigidity devolving from (3), a decrease in stability to perturbations, partly [following (1)] because increasing size brings on susceptibility to more kinds of environmental fluctuations. In these empirically discovered rules we have a splendid example of the kind of knowledge sought by science discourse, delivering a predictability generalizable to many kinds of systems, while ignoring uncanny particularities.

Complexity

The ideal of deterministic knowledge has recently been confounded by an emerging perspective on the natural world -- the realization that all natural systems are complex. There are numerous views on the nature of complexity, but they all involve the consequence that the traditional logical formulations of science -- equations and models -- can never capture enough of any natural system to be more than partially predictive. An important aspect of complexity is that systems tend to be organized in such a way as to be perturbed by historical contingency. Complexity involves a susceptibility to historical input, and so complex systems might well have been viewed as vitalistic in the Nineteenth Century (as when someone might have shaken a fist at, and cursed, a tornado that has just destroyed one's home -- even today we name hurricanes and typhoons, implicitly acknowledging their lifelike, and unforgivable, uniqueness and waywardness).

Complexity can be captured somewhat by the Aristotelian view of causality. Formal cause refers to local setups, themselves complex, which determine what can happen and how. Formality is comprised prominently by historically mediated local informational constraints. Material cause refers to the materials and laws that made the formal setup possible. Efficient cause is a trigger or forcing that initiates processes that will be mediated by the formal causes, and as such is completely historical in nature, determining when events will happen. Final cause refers to tendencies that entrain the results of the initiated processes in certain directions. An example would be the Second Law of thermodynamics which, by destabilizing energy gradients, makes available their energy to be utilized by processes initiated by efficient causes, deriving in the event the entropy required for universal energy equilibration.

Two special kinds of complexity can be found in natural systems -- extensional and intensional complexities, represented earlier in this essay as the scalar and specification hierarchies. Extensional complexity refers to the basic synchronic structure of the world, wherein larger scale systems, or ongoing processes, hold nested within them smaller scale ones, and are themselves nested within still larger scale systems, as in the scalar hierarchy: [biome [population [organism]]], interpreted as [higher level [lower level]]. The lower level helps to make possible the next one up, which is regulated by the one above that. The relation between scalar levels is one of indirect constraint since dynamical rates at the different scales are so different (by at least an order of magnitude) that they cannot directly interact. The result is dynamical complexity, frequently chaotic, caused by historically unpredictable alterations of the constraint relations between levels, each of which changes independently from the others, usually preventing synchronization -- or making it dangerously exceptional. So extensional complexity provides one way by which complex systems are susceptible to historical input.

Intensional complexity is doubly complex. In its synchronic sense it manifests the idea that complexity characterizes systems that can be analyzed in more than one, completely different, way. Consider the specification hierarchy: {physical process {chemical affinities {biological organization}}} (with the integrative levels interpreted as {lower level {higher level}}) -- thus, biology is built upon chemistry, which in turn materializes physical dynamics. Any biological entity can be understood using any of these discourses -- but not fully if missing information from any of them. Considering an ecologically important example, we have {entropy production {osmosis triggered by photosynthesis {evapotranspiration}}}. And from the point of view of the present essay, we may as well also note: {physical-chemical {historical}}. That is to say, vitalist cum historical phenomena are launched upon the physical-chemical, and depend upon it for support.

In the diachronic sense, intensional complexity implies that higher levels emerged sequentially from the lower ones, as in {physical phenomena -> {material phenomena -> {biological phenomena}}}, and more generally, {change -> {development -> { individuation}}}. This diachronic sense introduces change as a part of complexity; all dynamic systems are in transit, being neither fully (nor stably) this nor that, thereby being readily perturbable by impinging contingencies during the process of change.

Historical Ecology

The path dependence of historical phenomena can be illustrated with an especially illuminating case for ecology. Perhaps the most important discovery in historical ecology has been the pattern of evolution of herbivorous animals. One of the classical illustrations of systematicity in ecology is the way that animals complement plants in their biogeochemical role. Animals produce carbon dioxide and nitrogenous wastes from foodstuffs generated by photosynthesis in plants, which in turn utilize the animal wastes. In photosynthesis carbon dioxide is combined with water to make the basic energy sources for animal life plus oxygen, which also is used by animals. Thus animals and plants complement each other in their overall systems-ecological roles. As systematists, we would naturally visualize the producers evolving before, or at least simultaneously with their consumers. In fact plants were not the first living things to evolve, nor were their consumers the earliest kinds of animals to evolve. Photosynthesis was preceded, apparently, by a period of consumption of abiotically generated organic compounds by what amount to primitive detrivores, who also came to consume the remains of their own kinds. And the earliest animals did not take up their complementary role with respect to plants, but were carnivores. In every animal lineage, with the possible exception of mollusks, carnivores preceded herbivores, who could only evolve after achieving symbiosis with cellulose digesting microorganisms. Carbon dioxide and nitrogenous compounds were evidently plentiful enough in the early environment to allow plant photosynthesis to evolve without any animal complement other than detrivores. So the neat systematicity of modern ecosystems in this respect was only gradually put together by way of various tortuous historical paths. Vitalists might easily have concluded that Life on Earth must have searched out ways to produce this beautiful, and ultimately necessary, complementarity in many lineages simultaneously, imagining the operation of a Gaian final cause in this respect. Today the hegemony understands instead various fortuitous discoveries of the same ecological opportunity by way of random tinkering subsequently fixed by natural selection, with global finality being replaced by local opportunism.

It is of interest that both the vitalist intentional search model and the haphazard discovery model are assimilable to the equifinality principle of systems science, which implicitly brings them back into the fold of science by depriving the distinction between them of functional meaning. The complementarity of animal / plant metabolism would have been discovered either way, and it is that complementarity itself which is of significance ecologically, and it seems that its development would be inevitable. Harking back to organicism, we should note an important aspect of that discourse not yet referred to in this essay -- its holism. This too is motivated by a search for predictability. Consider the example of the chestnut blight in the early Twentieth Century in North America. The American chestnut was the dominant tree species in most eastern North American forest types. With the introduction of a fungus from Europe, the chestnut was completely eliminated in the course of some thirty years. Note the historical events here -- the contingency of a mutation in a fungus allowing it to parasitize the Eurasian chestnut; the contingency of its being carried to North America; the contingency of its behavior in that species completely destroying the American trees; the contingency of its dispersal throughout the eastern North American forests. But the result of these events was virtually undetectable in the forests. Other species -- ecological equivalents -- filled in the chestnut's role, and overall forest dynamics continued apace, as far as we can tell, with other species becoming dominant in different locales -- the whole being preserved.

This chestnut example has been used by historicists as an example of exactly the opposite hypothesis -- that there is no forest system whatever. They view ecosystems as mere haphazard collections of organisms that happened to be adapted to similar environmental conditions and that were able by chance to come to coexist. This controversy is part of the continuing dialectic between historicists and determinists.

Ecological Equivalents and Vegetations

General ecological roles such as the one relating animals and plants, or the putative forest role of the chestnut, can be assimilated to the Eltonian concept of the ecological niche. This version of the niche refers to general ways of life, like those of vultures, hawkmoths, or cacti, or the hagfish way of life, or that of gallinaceous birds. Such lifemodes have evolved independently several times in the history of life (by way of convergent evolution, and -- sequentially in time -- iterative evolution). These particular ways of life therefore represent ecologically predictable systemic roles involved in kinds of biomes, and again the historical paths to their discovery at different times and places makes little difference functionally. Of course, such ecological vicars are not identical, only similar. A good example to illustrate this is the comparison between chameleons and seahorses, because they are basically so different in underlying structure and habitat. These are similar in size and in the bushwhacking mode of predation, creeping slowly along on vegetation, then striking swiftly. Both are cryptically colored, have long prehensile tails, and both have independently moving eyes as well. Furthermore, seahorses bear live young, and so do some chameleons. The lack of identical form between such ecological vicars can, once again, be attributed to history -- in this case to the historically accumulated differences in the genes informing the ontogenies of the different kinds. Similarities like these, that are not inherited from similar ancestral systems, are not confined to organisms, but are found in whole vegetations as well. An example would be the pine barrens along the east coast of North America, where the northernmost and southernmost examples have no species -- and therefore no history -- in common. Just as thermodynamic properties transcend local kinetics, so vegetations transcend particular histories. Ecosystems can be viewed by determinists as structures involving multiple interlocking Eltonian niches.

Summary

Summing up, we can note that physical-chemical discourse focuses on natural kinds -- quarks, protons, water, quartz, tornadoes, or, more abstractly, toruses, vortices, waves and trees. These are constructed discursively in such a way that individual examples of given classes do not differ among themselves. This is achieved primarily by way of limiting the number of descriptive degrees of freedom to a few detectable by given technologies. It seems likely that no two examples of anything would be identical if we probe ever more deeply, but we can choose to describe things so that the individuality of instances is submerged under their more general properties. In this way, much of historically imposed nuisance is swept away, delivering more deterministic, predictable knowledge. In this way physical-chemical discourse has deliberately been constructed mechanistically.

As long as the eliminated degrees of freedom resided well below real time observational scale, we could conveniently conclude that the physical-chemical realm actually is mechanistic, at least in generating its easily detectable molar effects. But at the level of traditional ecological inquiry, the effects of historical contingency thrust themselves upon our view every bit as obviously as more general properties. Indeed, here we need to laboriously seek, or if necessary construct, the most general and stable properties using various statistical methods, deliberately ignoring other more variable properties -- the aim being, again, to make a useful mechanistic understanding. Today even physical-chemical discourse is being forced into a similar position as it takes up macroscopic systems like tornadoes or galaxies, which might be thought of as the ecosystems of physics.

It was in this context of the contrast between useful generality and untamable particularity that historicity was at first reacted to in science as being confoundedly vitalistic, while explicit vitalism became a mode of protesting the blatantly instrumental approach of a science gravitating in the direction of crass pragmatic application. Organicism later attempted to diminish this conflict by constructing form as more, or less, complicated. Then systems of simpler form could be viewed as those taken up by traditional science, while a new scientific approach would be needed to deal with complicated forms. Inasmuch as form ultimately derives from history, this dichotomy can be reworked as being between systems that can be constructed satisfactorily without taking into account their history and others where that is not possible. These latter, with their path dependency, are among those systems viewed as complex.

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