Alfred Russel Wallace and the Notion of Final Causes in Evolution

Charles H. Smith [a]

[a] Bowling Green, KY. Email: charles.smith@wku.edu

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Introduction

The methodology of Empiricism, with its emphasis on linking efficient causes to specific effects, has now dominated science for over three hundred years, and to productive end. Another of the other original Aristotelian concepts of causation, however, the notion of "final causes," has largely been ignored by the scientific community – perhaps because it seems to necessitate teleology, or even direct interventions ("first causes") from outside of the realm of natural process.

The most famous example of the operation of final causes comes down from ancient times. The sculptor is described as imagining what his completed form will look like, and then striving toward that end, modifying his work accordingly as he proceeds. There, a role for conscious awareness is assumed; it is much more difficult, however, to conceive of processes that invoke final causation, but unfold in the absence of "conscious" goals. Difficult, but by no means impossible.

Complex systems are by nature multi-causal; that is, their triumph over space and time is not via simple linear sequences of action, but instead through multi-directioned responses to complicated interplays of opportunities and constraints. It is easy enough to consider isolated examples of cause and effect individually, and to model them accordingly, but it is quite another matter to tease from such detail higher order principles that may be coordinating them. Certainly, conscious awareness is one such principle, as it organizes actions that might otherwise have to engage largely through trial and error, but one can also imagine forms of coordinated control that do not directly involve consciousness. The way the DNA molecule operates in connection with ecological context may be one of these.

In one sense, DNA represents a developmental regulator: ultimately, it unleashes the guiding program behind the individual's maturation into an adult organism. But in this instance there may also be a final cause operating, because not only is DNA responsible for developing an adult individual, but for developing one that will, on the average, fit into its environmental context in the same basic fashion its immediate ancestors did. In this case the ecological system within which the organism or population operates presents a kind of final cause, because DNA has evolved in a way recapitulating successful interactions between organism and environment to begin with. Natural selection is usually successful at mediating this balance between individual function and ecological continuity, but at times it fails to do so – either because DNA itself has found no way to shape a population of appropriately diverse mature individuals, or because the organism's environment has changed too quickly or completely to permit a workable form of organic response. In processes extending beyond the population, as we shall see below, natural selection plays a rather restricted role; instead, the main considerations must be: (1) to what degree the environment constitutes a kind of organization that itself encourages order-promoting forms of population engagement, and (2) to what degree, and for what reasons, change in the DNA molecule itself is encouraged or discouraged by latent factors (i.e., is DNA infinitely flexible, or is its further development constrained by *a priori* limitations?).

We have little further to say here about the second matter (though it is a question that may be a good deal more important than we currently acknowledge), but in a moment I will introduce several lines of research, actual or possible, related to the first. Before this, however, we need to take a short historical detour through the thought of that pioneer of evolution studies, Alfred Russel Wallace.

Final Causes Thinking in the Work of Alfred Russel Wallace

ALFRED RUSSEL WALLACE.

Figure 1. Alfred Russel Wallace, circa 1877. From the 1891 pamphlet *Alfred Russel Wallace* (New York: D. Appleton and Company), by Edward Drinker Cope.

Alfred Russel Wallace was born in early 1823 and died in late 1913. For about three-quarters of that nearly ninety-one year period he immersed himself in the study of evolution: physical, biological, and social. Even before he left for South America in 1848 on his first major collecting expedition he was contemplating the subject, but it was not until 1858, where he was working in the remote regions of Indonesia, that the important pieces fell into place. Nevertheless, by 1855 (and likely earlier – perhaps as much as ten years earlier) he already knew how to demonstrate that organismal evolution had in fact taken place; his conclusions are related in the famous Sarawak Law paper "On the Law Which Has Regulated the Introduction of New Species."[1] This essay, generally recognized as a cornerstone work in the then-emerging field of historical biogeography, focused on the idea that the most closely related species could also be found most closely associated in both time (as part of the geological record) and space (in their geographical ranges), an empirical fact that was difficult to explain by any other means than a divergence of forms over time.

Wallace stopped short, however, of invoking an evolutionary explanation for the patterns he described; he merely pointed them out. Thus the paper said nothing about possible mechanisms: it dealt only with the *results* of evolution. And, in fact, he was having a difficult time connecting the macroscale to what was going on at the level of individual function – in particular, to the relationship between adaptation the process, and adaptation the result. Even after 1855 he apparently regarded adaptive structures as having arisen more or less randomly, or at the most being "correlated with" independently organized evolutionary inertias. He didn't know what, but it seemed that some large scale environmental force – perhaps climate or geological change – was slowly but inexorably guiding evolution along (possibly, by causing already existing adaptive structures to be favored in one direction or another).

These rather "geographical bauplan"-like thoughts on evolution were probably related to Wallace's reluctance to assign particular causal influences to particular adaptive structures; he likely regarded such thinking as necessarily implying an involvement of first causes – roughly, Godly interventions. This conservative pattern of thought lay very close to the center of his world view, and on many future occasions[2] he would warn that regardless of what we see and understand in the more restricted sense, there are always "more recondite forces" operating in the world around us. His recognition of the principle of natural selection in 1858 had no real effect on this point of view, and shortly thereafter he began supplementing it with a corollary: that no one should expect a recognized principle of nature to explain everything, just those facts related to its specified domain.[3]

Natural selection actually created quite a problem for Wallace's philosophy of nature. Contrary to what is commonly assumed, there is no demonstrable evidence that before 1866 (even in 1858) he believed natural selection could account for the higher mental and ethical attributes of humankind – yes, he did now have a model that set out a logical relationship between *particular* causes and *particular* biological results,[4] but he still could not explain the presence of characters such as mathematical thinking and ethical behavior that appeared to have no logical connection to the selection process. Nevertheless, confident that the natural selection concept worked within the logical limits he had identified for it, he set aside the matter of what "more recondite force" might explain its human exceptions, and moved on for the time being.

By late 1866 Wallace had decided that the phenomena of spiritualism provided the appropriate explanation for the "exceptions." Wallace's spiritualism had nothing to do with religious belief or any interest in sensationalism; instead, he simply thought he had found evidence of an extension of natural causality to an aspatial, nonphysical reality. He still did not feel that conscious acts, including moral agendas and the use of logic and mathematics, could be explained as having originated through the process Herbert

Spencer had dubbed “the survival of the fittest.” Spiritualism was in effect Wallace’s theory of supra-consciousness; through it he could recognize “more recondite forces” in the form of spirit entities that relayed potentially helpful information to us material beings through dreams and other subtle psychic influences. As recipients of such “feedback” we might actually use this information or not (but ostensibly we frequently did, and more often than not, profitably) – and thus its means of delivery was no more deterministic than how various incipient physical adaptations were selected for or against in a biological context. In theory, bad thoughts and ideas might slowly be removed from the population, both because we would increasingly “come to our senses,” and because “coming to our senses” would lead to an increasing rejection of persons displaying bad motives and actions – with the latter finding it more and more difficult to obtain mates, and pass their deficiencies along to offspring.

A close examination of Wallace’s approach to natural selection suggests he had adopted a parallel position with regard to the more strictly biological aspects of evolution. Importantly, Wallace regarded natural selection as being, more exactly than the “survival of the fittest,” the “elimination of the unfit” – and he says so, directly, in several of his essays.[5] In this view, natural selection is seen as the way a population is kept “up to snuff,” as it were, in its relation to its overall environment – an ecological process, not an evolutionary one. So he did recognize a difference between evolution on the one hand, and natural selection on the other. In his *Contributions to the Theory of Natural Selection* he provides a logical derivation of natural selection on page 302, in effect portraying it as a “law,” akin to Newtonian gravitation, and not as a theory at all. It is therefore not surprising that he refers to the concept as the “law of natural selection” in many of his writings from the 1860s on.

Wallace’s concept of “adaptation” basically emerges as a state space – that is, as a stochastic transfer of information between the organism or a population thereof and the environment (and here it is important to regard the term “environment” in a most general way, consisting of all elements of the organism’s surroundings: biological or physical, and even other organisms of the same species). This transfer is what keeps the ecosystem functioning as a discrete entity as energy cascades through it, degrading as it does so. Everything must be “in the right place at the right time” to make it all work. Organisms are DNA-propelled automatons, brought into being under the tacit result that things will be roughly what they were before to allow the cascade to continue. “Change” is therefore possible only when the environment changes, or at the very least when there are changes in the characteristics of an organism’s (or population’s) interaction with that environment. Wallace has frequently been distinguished from Darwin on the basis of the former’s greater emphasis on environmental causalities in evolution (for example, on the effects of climate more than behavior), but such thinking significantly oversimplifies the differences between the two men’s approaches. Darwin did not much discriminate between the notions of “being adapted” and “adapting,” with the result that some have complained there is a tautological weakness to his thinking. (As the biologist Richard Lewontin once put it, “The process is adaptation and the end result is the state of being adapted . . . The problem is how species can be at all times both adapting and adapted.”[6]) Wallace, on the other hand, has sometimes been criticized as a hyperselectionist – that is, for allegedly believing that all adaptive change had to be attributed to the action of natural selection (whereas Darwin believed that additional influences, such as the inheritance of acquired characters, helped it along). Wallace did in fact argue (as did Darwin) that every adaptation had to have come into being for reasons related to use to the organism (or in close correlation with some structure that was useful), but the hyperselectionism tag is really a red herring. To begin with, Wallace was aware that other kinds of causalities were involved – he sometimes complained, especially, that while one might understand natural selection as acting upon existing variation, the origins of variation itself (as we would now explain in the main through mutation) were completely unknown!

But we digress . . . If we really wish to differentiate between Darwin's and Wallace's approaches, we need to look at a matter more fundamental than whether one supported sexual selection[7] or "environmental selection" more than the other – again, from the point of view of the individual, everything that is not it, *is* "the environment." It is Wallace's focus on the "removal of the unfit" that really distinguishes his thinking from Darwin's, which is permeated by implicit allusions to trees, phylogeny, and adaptationism: historical tracings. Wallace's ecological emphasis provides a simpler logic, because it recognizes no *process* of adaptation. Instead it identifies a state space, or perhaps filter, connecting the *potential* that adaptive structures have to engage with environment with independent definitions of the way that environment might receive such actions.

Historically, at least two important writers have noted this uniqueness to Wallace's approach: C. Lloyd Morgan and Gregory Bateson. In 1888 Morgan wrote:

> Those who have read the recently-published "Life of Charles Darwin" may remember a footnote in which Mr. A. R. Wallace criticizes the phrase "Natural Selection." "The term 'Survival of the Fittest,'" he says, "is the plain expression of the fact; 'Natural Selection' is a metaphorical expression of it, and to a certain degree indirect and incorrect, since Nature does not so much select special varieties as exterminate the most unfavourable ones." . . . Mr. Herbert Spencer's term, ''Survival of the Fittest," says Mr. Wallace, is the plain expression of the fact; "Natural Selection" is a metaphorical expression of it. Yes; but in the first place, Mr. Spencer's phrase gives no inkling of the process by which such survival is brought about; and, in the second place, it is questionable whether any phrase, which does so indicate the process, can escape the charge of being in some degree metaphorical. The sting of Mr. Wallace's criticism, therefore, would appear to lie (appropriately) in the tail, where he points out that Nature does not so much select special varieties as exterminate the most unfavourable ones. This seems to me a valid criticism; one which Mr. Darwin does not sufficiently meet; and one which still holds good.[8]

And more than a hundred years later it still holds good. Morgan goes on to propose the phrase "natural elimination" as a way of keeping us alert to this weakness, but the term never caught on.

In the 1970s, anthropologist Gregory Bateson took up the discussion. In 1972, in his celebrated *Steps to an Ecology of the Mind*, he commented on an analogy Wallace used in his 1858 essay to help explain the way natural selection acted ("The action of this principle is exactly like that of the centrifugal governor of the steam engine, which checks and corrects any irregularities almost before they become evident; and in like manner no unbalanced deficiency in the animal kingdom can ever reach any conspicuous magnitude, because it would make itself felt at the very first step, by rendering existence difficult"[9]):

> . . . The steam engine with a governor is simply a circular train of causal events, with

> somewhere a link in that chain such that the more of something, the less of the next thing in the circuit . . . If causal chains with that general characteristic are provided with energy, the result will be . . . a self-corrective system. Wallace, in fact, proposed the first cybernetic model . . . Basically these systems are always *conservative* . . . in such systems changes occur to conserve the truth of some descriptive statement, some component of the *status quo*. Wallace saw the matter correctly, and natural selection acts primarily to keep the species unvarying . . . [10]

In his 1979 collection *Mind and Nature: A Necessary Unity*, Bateson added: ". . . If it had been Wallace instead of Darwin [who started the trend], we would have had a very different theory of evolution today. The whole cybernetic movement might have occurred one hundred years earlier as a result of Wallace's comparison between the steam engine with a governor and the process of natural selection . . ." [11]

Sadly, few other observers have recognized the logic inherent in Wallace's thinking, and as a result we are still saddled with the philosophical and methodological inelegancies of Darwinian "tree thinking" and "adaptationism."

In summary, in Wallace's world view there are both conventional material organizing principles, and ones he assigned to a "realm of spirit," or possibly to consciousness in general. But Wallace would have nothing to do with creationist "first causes": he thought that both material and nonmaterial reality operated on the basis of investigable properties. That is, both spatially-extended processes and nonphysical processes were "natural" and "law-based," in the conventional sense of both terms. Whether Wallace was right in detail is not at issue at the moment; what is more interesting is that he used this view to come up with a range of ideas that turned out to be correct, and others that have yet to be proved incorrect. It is therefore fitting that some real attempts be made to come to grips with his world view, as it may lead to other lines of thought that simply have not occurred to us yet.

Wallace has often been accused of attempting to introduce teleological thinking into scientific endeavor, and while some of this criticism is just, it must be remembered that "teleology" and "final causes" are not quite the same thing. Even the super-mechanist August Weismann acknowledged this, as Wallace pointed out in a book review of Part III of his work *Studies in the Theory of Descent* in 1882:

> The second, and concluding essay, is entitled "On the Mechanical Conception of Nature," and is chiefly occupied with an inquiry into the true character of variation as the chief factor in evolution, and into the comparative importance of external conditions, and the constitution of the organism in determining the particular direction of the course of development; the object being to show that all takes place according to fixed laws without the interference of any "teleological principle," whether in the form of a "phyletic vital force" or the interposition of any "designing power." The writers whose views on these subjects are combated are Von Hartmann and Karl Ernst von Baer, and, after an elaborate and often subtle argument, Dr. Weismann concludes that the facts can all be explained on "mechanical" principles, or, as we should say, by the action of fixed laws. He is however careful to add that this does not imply a materialistic view of nature. "Those who defend mechanical development will not be compelled to deny a teleological power, only they would have, with Kant, to think of the latter in the only way in which it can be conceived, viz. *as a Final Cause*." And on the great question of the nature and origin of consciousness he thus expresses himself:– "If it is asked, however, how that which in ourselves and in the

> remainder of the animal world is *intellectual* and *perceptive*, which *thinks* and *wills*, is ascribable to a mechanical process of development – whether the development of the mind can be conceived as resulting from purely mechanical laws? I answer unhesitatingly in the affirmative with the pure materialist, although I do not agree with him as to the manner in which he derives these phenomena from matter, since thinking and extension are heterogeneous things, and one cannot be considered as a product of the other." And he intimates that the fundamental notion of conscious matter may get us out of the difficulty. However this may be, he maintains that the theory of selection by no means leads – as is always assumed – to the denial of a teleological Universal Cause, and to materialism, but only to the belief that any mode of interference by a directive teleological power, other than by the appointment of the forces producing the phenomena, is, to the naturalist, inadmissible. "The final and main result of this essay will thus be found in the attempted demonstration that the mechanical conception of Nature very well admits of being united with a teleological conception of the Universe." [12]

Can We Recognize Specific Final Causes in Nature?

With these Wallacean thoughts in mind, we may now turn to a description of some natural contexts (especially, geographical ones) that potentially invite final causes thinking. These all involve my own research; some of this has been published over the years in conventional venues, and some, being more explorative, is described only in several websites I have maintained for a number of years. My involvement in this kind of work has taken three forms.

Can Selection be Resisted by Intervening Counter-Purpose?

Since the 1980s I have been interested in the notion that there may be intervening large-scale environmental forces to which living things may have difficulty adapting. Two examples of this kind of thinking follow.

The first concerns the varying hare, *Lepus americanus* (and its close relatives in Eurasia), whose populations are well known to undergo dramatic cycles in numbers in the northern coniferous forests of both the New and Old World. These cycles have a period of about nine or ten years, and while progress has been made in understanding the local dynamics and demography of this phenomenon, food chain-related and otherwise, less progress has been made in understanding the bigger picture. This is a highly organized system, with detailed continental-level surveys of annual trends [13] having shown that repeated waves of increase and decrease spread out over immense areas. Such has been the case in North America, at least, since before the early days of European settlement.

Investigators have searched in vain for some kind of climatic or astronomical (*e.g.*, sunspot cycles) influence that cycles in the same period; this of course might provide a simple chain of causality. Meanwhile, populations of other creatures involved directly or indirectly with the hares as a part of their food chain are also observed to cycle in ten-year periods. A large literature has evolved around the question, with most studies focusing on demographic features of the populations as they wax and wane. [14]

But it is doubtful that demographic explanations alone can account for such a regularly occurring process over two continents; consider that the wave of increase/decrease travels much faster (nearly a thousand miles a year) than could the individual organisms themselves. It seems more likely that some kind of almost harmonic interaction between population and environment is involved, though this may not necessarily involve a causal force that is itself cycling. Instead, we might consider a juxtaposition of several long-term and large-scale influences.

Suppose, for example, that the recent glacial periods forced the hare populations southward to where usefulness of white color and resistance to photosensitive pigment-laced foodstuffs were no longer selection factors, and they lost these adaptations. On returning northward, to where the geomagnetic field channels more high energy particles flowing in from outer space toward the surface, their color change and loss of resistance leads to fundamental metabolic and physiological disturbances altering their life habits, and ultimately the stability of food chains. Evidence: (1) the fact that the most affected portions of the populations' ranges coincides very closely with the related magnitudes of the geomagnetic field (2) the fact that historically one of the most reported symptoms of hare behavior during these cycles is the incidence of what has been called "shock disease," the symptoms of which closely resemble the symptoms of photosensitivity disorders such as eczema – from which, by the way, some protection may be gained by having a dark-colored pelt. In theory, until the gene pool identifies a solution to both selection pressures, we may expect continuing cycling (the details of which can then be understood through the demographics of life cycle and food chain relations). Note that here we have a possible instance of a combined final cause (cosmic radiation and range shift) generating a condition through the imposition of intervening circumstances.

To determine whether this theory holds water one would have to examine the hare's food supply for photosensitive pigments, tracing this through to any possible photosensitivity disorders. Interestingly, there are known connections between photosensitivity and reproduction in lagomorphs,[15] and perhaps a disruption in the normal sequence of reproduction – causing higher rates of reproduction, or at different times of the year (serving to avoid predators or make use of different foodstuffs, for example), or . . . ? – may be the triggering mechanism for sustaining a population cycle. Further, it has been suggested[16] that the cycle may be related to two different morphs within the population fighting it out, as it were, for dominance, and the two morphs may be reacting to the photosensitivity stress differently at different points of the cycle (*e.g.*, offspring from one of the two morphs may survive better than those from the other under the stress of high population levels).

If the snowshoe hare's cycles may be relatable to a selection regime under unique spatial-temporal circumstances, the demise of the dinosaurs might represent something more commonplace in the history of life. The asteroid impact theory of their extinction near the Cretaceous-Tertiary boundary set forth by Walter Alvarez and his colleagues in 1980[17] has remained in vogue for more than three decades, yet there are still dissenting voices, and alternative, or at the least extenuating, theories continue to emerge. Some of the facts still don't quite add up; there is evidence, for example, that dinosaurs were already in considerable decline at the time of the collision.[18] A largely overlooked fact concerns the nature of the victims of the extinction: although large creatures seem to have been heavily victimized, some fair number did survive – but rather more remarkably, entire greatly speciose groups went extinct, including ones that had many medium- or small-sized species (even the dinosaurs were not all giants). The tendency for the extinction to have affected entire groups – that is, to have unfolded along phylogenetic lines – invites explanations connected to physiology more than it does ecology. Perhaps in this instance certain commonly-shared traits proved fatal, with the results being exacerbated secondarily by food chain relations.

In particular, one can imagine a kind of scenario in which natural selection is powerless to save whole groups from extinction. One might think this *a priori* impossible, but there may be circumstances in which the changes that are needed to survive are physiological responses to ambient conditions, and the only possible workable adjustments run afoul of ecological counter-purposes.

According to a recent estimate, [19] atmospheric oxygen levels rose almost without ceasing over the entire period of the dinosaurs' existence (to approximately double what they were in their earliest days). It seems that no one has considered the possibility that the initial dinosaur physiological game plan was not well-suited to alter itself to deal with this stress: remember, oxygen is a physiological poison that although vital to metabolism, must also be protected against as a direct agent. Adapting to such a change might be very difficult, because it would effectively mean creating structures designed to reduce oxygen utilization, an outcome that might well conflict with the need to remain ecologically robust. There are quite a few lines of evidence that can be used to support this theory, as summarized in a paper I have put up online at one of my websites. [20] Here, we can at least briefly list some of the more interesting ones: (1) all dinosaurs were relatively large (and thus all would have been affected) (2) the reason for the survival of birds, mammals, and other (not endothermic) reptiles becomes straightforward (3) the expansion of dinosaur populations to colder climates in the Cretaceous (a way of changing the body's heat regulation regime) (4) the increasing number of morphological peculiarities in the later dinosaurs (crests, sails, etc.), which might have aided in heat regulation (5) the extinction of whole families and orders (suggesting physiological commonalities more than single ecological causes) (6) and the tendency of primitive living representatives of ancient groups to be rather sluggish, and/or associated with oxygen-poor environments.

Natural Selection in Conjunction with Biogeochemical Cycling Regimes

The preceding scenarios represent possible circumstances under which natural selection is either rendered powerless, or is forced to work at counter-purposes as a result of historical accident. Other such scenarios can doubtlessly be imagined; at the very least it is worthwhile considering whether evolution is always "forward moving," or instead in some cases responds to reversals occasioned by time-lagged eventualities. This is doubtlessly true in many contexts: in geomorphology, for example, work in the 1980s suggested that because of space-filling constraints stream system evolution often does not follow a simple most-probable state form of development. [21]

Still, it is probably true that most sequences of organic change on the surface of the planet are less episodic, closely related to the direct constraints and opportunities of day to day existence, and referable to slowly unfolding probabilities. Yet here too we can imagine the possible existence of final causes that impact the way evolution proceeds. A number of years ago I explored the notion that organisms may disperse, more or less uniformly (though at differing rates) in preferred directions, the results contributing to reductions in the inefficiency of operation of local and global biogeochemical cycles.[22] Beginning with Wallace's "elimination of the unfit" stance and Bateson's points, I argued that natural selection might be viewed as the negative feedback element in a process leading to evolution in the longer term. In this view, again, adaptations are viewed only as structures creating a *potential* for evolution; that is, they mediate environmental involvement exemplified by the ingestion of foodstuffs, seeking of cover, and other behaviors. If in fact this engagement involves a preferred movement – migration, dispersal, etc. – toward places inherently facilitating the kinds of selection that encourage perpetual changes – as opposed to high specialization of a very restricted "being in the right place at the right time" type more likely to result in extinction – then this is automatically evolution. Natural selection itself maximizes the efficiency of this process by ensuring that, probabilistically, the best-suited individuals remain to operationalize the assembly.

One important element of this model is the notion that the stresses that restrict community development are bi-directional: that is, that there is as much significance to there being "too much" of a critical resource (in particular, water) as there is to there being "too little." Thus, tropical rainforests, despite their warm temperatures and high moisture levels, are as highly stressed environments as deserts are, since there are as many ways that an excess of water contributes to a reduction in long-term evolutionary potential as there are ways that its absence does. Of course, in the one instance one ends up with a community structure filled with species highly specialized toward interactions with other organisms, while in the other the specialization is more in response to physical environment – but each is still specialization, and is likely to either result in rapid extinction, or a speciose radiation of closely similar forms from which new generalist lines cannot emerge. By contrast, productivity-rich environments such as midlatitude grasslands, which in moisture terms are low-stress, force relatively fewer future-limiting adaptations: that is, the selection that goes on is less focused on "particular time and place" concerns. This also in theory makes it easier for them to accommodate in-dispersing populations.

From this I surmised that evolution proceeds as a function of the tendency of (all) populations to disperse in directions of lower (moisture) stress (again, primarily because it is easier for dispersing populations to select out functioning adaptive characters in such areas). Because the environment is thus in effect "guiding" populations in a (spatially) nonrandom way, evolution is occurring *ipso facto* because the adaptations emerging there are more likely to contribute to sustained changes. For my Dissertation project[23] I performed an analysis of range distributions of vertebrates in the central U.S. region and actually found evidence that one of the important deductions deriving from such an understanding of "stress" – that (expanding) range boundaries should tend to parallel isolines of stress as mapped out – apparently was true. In a recent informal study (also placed online[24]) using the same data, I found out that there was a high correlation (r = -.89) between level of moisture stress and the number of recognized subspecies found across the entire range of mammals found at a sample of locations; this suggests that potential of eventual divergence/biodiversity is related to the model of stress entertained. In a paper in *Progress in Physical Geography* its author refers to this work as "perhaps the most robust theory of evolution at the ecosystem and biospheric scale, encompassing thermodynamic and energetics arguments, and specifically leading to maximization of the rates of both energy flux and biogeochemical cycling."[25] Yet to my knowledge no one has tried to develop it further.

The Ultimate in Final Causes: Restrictions on Structural Expression in Extended Space

A third way to consider the possible role of final causes in evolution moves away from the realm of biology altogether. In a letter to the editor concerning an ongoing discussion on the “fourth dimension,” Wallace once said: “I hold, not only that the alleged fourth dimension of space cannot be proved to exist, but that it cannot exist. The whole fallacy is based upon the assumption that we do know space of one, two, and three dimensions. This I deny...”[26] Wallace’s point must be read between the lines: he denies that “space” is to be considered a concept limited by geometry. I agree with him. For over twenty years I have been examining, albeit slowly, the idea that space evolves by virtue of its component elements, and in particular that its components cannot express themselves *as* space, and thus exist as material entities, unless they exhibit a particular plan of subsystemization. That is to say, there may be “rules” of energy/information exchange among the subsystems that are common to all natural systems – individually, hierarchically, and probably as a whole – and three-dimensional space represents the projection of such balanced exchanges.

This notion sounds like something out of the writings of Benedict de Spinoza, and in fact that is exactly where the idea came from. In his *Ethics* Spinoza deduced his version of the natural system, offering up proofs for his conclusions that it appears no one fully understands. In Spinoza’s reality, there is an underlying, transcending existence he refers to as “Substance”; this is not perceptually accessible to mere mortals, being expressed only indirectly, through two (super-) attributes he refers to as “Thought” and “Spatial Extension.” These are not “attributes” of the type we now normally think of, however, but instead what might be described as “rules of order” that are ultimately responsible for organizing Substance into the tangible reality. It is in theory the operation of these “rules of order” that produces individual, measurable entities – which Spinoza refers to as “modifications.”

In a pair of publications in 1986, and then one in 2015[27] I suggested that Spinoza’s model might actually be explorable were his “rules of order” to represent rules of subsystemization applicable equally to all existing natural systems. In these papers I worked out a “lazy universe” form of subsystemization through simple combinatorial mathematics; the result was a series of tree structures, as portrayed in Figure 2.

While this formulation might have relevance to the study of how systems emerge in a historical sense (to, for example, human embryological development, or the interrelation over time of emerging tectonic plates), it seems to have no implicit connection to any possible constraints there might be on the actual spatial extension of systems. That is, what kind of “rules of organization” might underlie expression as a physical world, “spatially extended,” structure? Some years after the 1986 papers, a hypothesis suggested itself: that flows of energy/information among some small number of subsystems (that in sum constitute the whole system) might self-organize as an entropy maximization process. The key here was to imagine a form of entropy maximization that might project as a three-dimensional space.

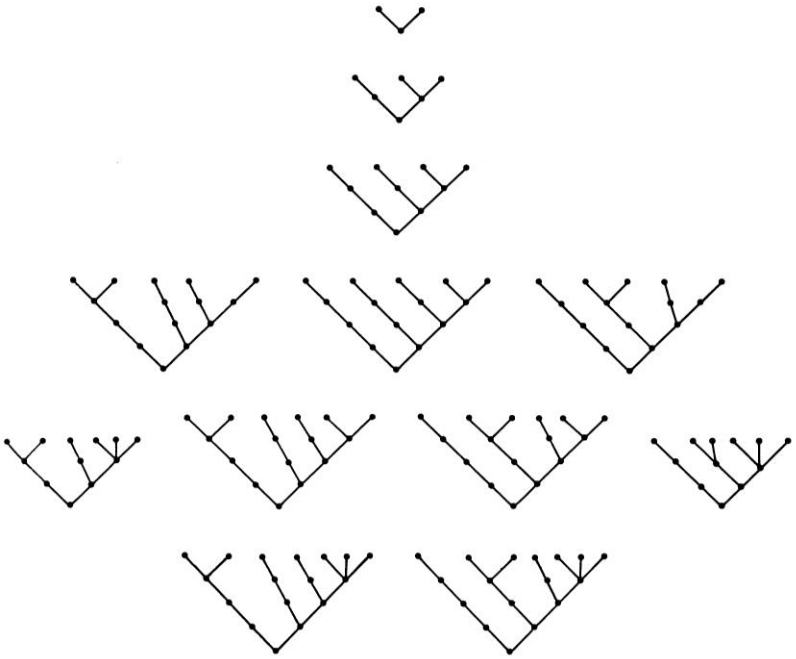

Figure 2. The figure shows a developing hierarchy within which all inclusion series obey most-probable state criteria. For example, within the trees containing n = seven initial class elements, these seven group most-probably into four class elements in the pattern 2-1-1-3; similarly, five initial elements group most-probably into two classes in the pattern 2-3, and four initial elements group most-probably into two classes in the pattern 3-1. These kinds of relationships cannot be extended beyond the n = 7 condition.

It turns out that these thoughts lend their way to some fairly easily executable simulations that indicate whether such a theory could possibly hold water. Specifically, one can run a series of entropy maximization operations on n by n matrices filled with random numbers, and determine whether any of the solutions will "project" as a set of relations interpretable as a three-dimensional space. It was found that only matrices of order n = 4 will do so. About 0.2 % of the many tens of thousands of matrices I examined produce results of this type, but this is enough to sustain an evolving system with infinite variations!

The same basic method can be applied to the analysis of actual systems, though the trick is to find some measure of system function that, as sampled in space, is equally applicable across the whole of the system. Over the years I have performed a number of pilot analyses on real world systems that seem to fit this bill; all of these studies have focused on the spatial autocorrelation properties of some diagnostic character as it varies in magnitude spatially. [28] The studies have involved: (1) stream basins (the measured variable being elevation above sea level, a measure of potential gravitational energy at each point in the basin) (2) the interior zonation of the earth (the relative spatial locations of the core, outer core, mantle, and surface zone provide the basis for analysis) (3) a regional city system (the varying densities of human population across the region, as spot sampled) (4) color patterns on butterfly wings (5) valence shell-filling within some simple molecules, and (6) the topographical profile of the earth's surface. All show at least some support for the theory, with the first two of these producing particularly intriguing results. [29]

Although this work admittedly derives from an unusual starting point, should it actually be proven to have merit in the sense envisioned the rewards could be considerable. To begin with, it would provide a final verdict on the long-existing question of why we exist in a three-dimensional world – the last word in final causes! More than this, however, it could provide a starting point for both theoretical and applied studies that enhance existing approaches by recognizing certain very strong constraints on the range of outcomes that are possible at any given point of a system's individual course of existence. For example, it would become possible to create very detailed models of earth surface zone geometry over geological time by combining the results from studies (2) and (6) mentioned above (and recent study suggests that a third aspect of the problem, the relative spatial contiguities of the four primary surface zone constituents – atmosphere, ocean, and oceanic and continental crusts – also fits the model). Most intriguing of all, I think, is the potential for application within the realm of medical imaging. Fine-mesh sampling of such characteristics as, for example, brain temperature (or possibly electrical activity), followed by second-order analyses of the type alluded to above, might identify systemic differences between healthy and diseased individuals – even between individuals who are healthy, and those who are in the very initial stages of some kind of deterioration.[30] In short, a very powerful aid to preventive medicine might be made available.

Conclusion

In this paper a look has been taken at the matter of final causes in nature. In the nineteenth century, one of the few people who were doing the kind of work that lent itself to scientific studies invoking final causation was Alfred Russel Wallace. Wallace believed that there were ever-more recondite forces involved in the operation of nature, and was willing to take the evidence to where it led. This style of thinking has gone out of vogue, and we have become satisfied – perhaps too satisfied – with explanations of nature that deal with limited-scale causes and effects. We have largely given up on the idea that complex systems may be based on more complicated properties than can be identified in reductionist terms. I have given examples of some of the kinds of causality I feel could be in operation; it is too early to say whether any of these ideas will ultimately be borne out, but they are designed to give pause for thought. Certainly, additional scenarios of similar kind can be imagined.

Notes

1. Wallace, A. R., Sept. 1855. "On the Law Which Has Regulated the Introduction of New Species." *Annals and Magazine of Natural History* 16 (2nd s.): 184-196.

2. In 1885 Wallace wrote: "Equally absurd is the allegation that some of the phenomena of Spiritualism 'contradict the laws of nature,' since there is no law of nature yet known to us but may be apparently contravened by the action of more recondite laws or forces" (*The Medium and Daybreak* 16: 809-810, on p. 809). See also comments in "On the Habits of the Orang-utan of Borneo," 1855, *Annals and Magazine of Natural History* 18 (2nd s.): 26-32, on pp. 30-31.

3. In 1867 he wrote: "It is, therefore, no objection to a theory that it does not explain everything, but rather the contrary" (*Transactions of the Entomological Society of London* 4 (3rd s.), part III: 301-416, on p. 309). See also comments in: "Remarks on the Habits, Distribution, and Affinities of the Genus *Pitta*," 1864, *Ibis* 6: 100-114, on p. 111; "Man and Natural Selection," 1870, *Nature* 3: 8-9, on p. 9; and "Evolution and Character," 1908, *Fortnightly Review* 83 (n.s.): 1-24, on p. 1.

4. This was the main reason why the development of the theory of protective mimicry was so important to the success of natural selection as an explanatory model: clear results could be attached, with mathematical precision, to the nature of the selective force involved.

5. In 1890 he wrote: “The survival of the fittest is really the extinction of the unfit” (“Human Selection,” *Fortnightly Review* 48 (n.s.): 325-337, on p. 337). See also comments in: “Evolution,” 23 December 1900, *The Sun* (New York) 68(114): 4-5, on p. 5; and “The Colours of Animals,” 1877, *Macmillan's Magazine* 36: 384-408, on p. 405.

6. Lewontin, R. C., 1984. “Adaptation.” In: *Conceptual Issues in Evolutionary Biology*, Sober, E., Ed. (Cambridge, MA: MIT Press): 235-251, on pp. 237-238.

7. It should be noted in this context that the two’s differences over the import of sexual selection reduce to a disagreement as to specific mechanism rather than a philosophical schism: sexual selection is, in the last analysis, just a delimited form of natural selection. In the most general understanding (Wallace’s) of natural selection, “the environment” provides the source of the selecting effect, and it makes no difference philosophically whether the immediate selector is a physical or a biological agent.

8. Morgan, C. Lloyd, 1888. “Elimination and Selection.” *Proceedings of the Bristol Naturalists’ Society* 5(3), n.s.: 273-285, on pp. 273-274.

9. Wallace, A. R., 20 August 1858. “On the Tendency of Varieties to Depart Indefinitely From the Original Type.” *Journal of the Proceedings of the Linnean Society: Zoology* 3(9): 53-62, on p. 62.

10. Bateson, G., 1972. *Steps to an Ecology of Mind*. San Francisco: Chandler Publishing Co., on p. 435.

11. Bateson, G., 1979. *Mind and Nature: A Necessary Unity*. New York: Dutton, on p. 43.

12. Wallace, A. R., 18 May 1882. review of *Studies in the Theory of Descent Pt. III* by August Weismann. *Nature* 26: 52-53, on p. 53.

13. In the 1930s and 1940s an annual survey of varying hare population trends was carried out throughout its range, chiefly under the direction of Charles Elton and Dennis Chitty. Results were published yearly in the *Canadian Field-Naturalist* and the *Journal of Animal Ecology*. See also: Smith, C. H., “Spatial Trends in Canadian Snowshoe Hare, *Lepus americanus*, Population Cycles,” 1983, *Canadian Field-Naturalist* 97(2): 151-160.

14. See reviews by: Keith, L. B., 1963, *Wildlife’s Ten-Year Cycle* (Madison: University of Wisconsin Press); Keith, L. B., 1987, *Demography and Ecology of a Declining Snowshoe Hare Population* (Washington, D.C.: Wildlife Society); and Berryman, A., 2002, *Population Cycles; The Case for Trophic Interactions* (New York: Oxford University Press).

15. See for example: Ben Saad, M. M., & D. L. Maurel, 1 February 2002. “Long-day Inhibition of Reproduction and Circadian Photogonadosensitivity in Zembra Island Wild Rabbits (*Oryctolagus cuniculus*).” *Biology of Reproduction* 66(2): 415-420.

16. Sinclair, A. R. E., D. Chitty, C. I. Stefan, & C. J. Krebs. 2003. “Mammal Population Cycles: Evidence for Intrinsic Differences During Snowshoe Hare Cycles.” *Canadian Journal of Zoology* 81: 216-220.

17. Alvarez, L. W., *et al*., 1980. “Extraterrestrial Cause for the Cretaceous-Tertiary Extinction.”

Science 208: 1095-1108.

18. Macleod, N., *et al*., 1997. “The Cretaceous-Tertiary Biotic Transition.” *Journal of the Geological Society, London* 154: 265-292.

19. Lane, N., 2002. *Oxygen; The Molecule That Made the World*. New York: Oxford University Press.

20. See: http://people.wku.edu/charles.smith/once/finalc.htm Also note the general relevance of the thoughts presented here to the discussions on the concept of maladaptation: See for example, Brady, S. P. *et al.*, 2019, “Understanding Maladaptation by Uniting Ecological and Evolutionary Perspectives.” *The American Naturalist* 194(4): 495-515; Brady, S. P. *et al.*, 2019, “Causes of Maladaptation.” *Evolutionary Applications* 12: 1229-1242.

21. Abrahams, A. D., 1984. “Channel Networks: A Geomorphological Perspective.” *Water Resources Research* 20(2): 161-188.

22. Smith, C. H., 1984, *The Dynamics of Animal Distribution; An Evolutionary/Ecological Model* (Ph.D. Dissertation, Dept. of Geography, University of Illinois at Champaign-Urbana); Smith, C. H., 1986, “A Contribution to the Geographical Interpretation of Biological Change,” *Acta Biotheoretica* 35(4): 229-278.

23. *ibid*.

24. http://people.wku.edu/charles.smith/once/dissadds.htm

25. Phillips, J. D., 2008. “Goal Functions in Ecosystem and Biosphere Evolution.” *Progress in Physical Geography* 32(1): 51-64, on p. 56.

26. Wallace, A. R., 29 September 1894. “The Fourth Dimension.” *Light* (London) 14: 467.

27. Smith, C. H., 1986. “A General Approach to the Study of Spatial Systems” (parts one and two). *International Journal of General Systems* 12(4): 359-400; Smith, C. H., 2015 “’In’ or ‘As’ Space?: A Model of Complexity, with Philosophical, Simulatory. and Empirical Ramifications.” *International Journal of Design & Nature and Ecodynamics* 10(3): 233-241.

28. To fill the 4 by 4 matrices for entropy maximization analysis, the subject variable is first spatially (grid) sampled and then cluster-analyzed into classes based on varying magnitude (in some instances the class structure is already evident). Spatial autocorrelation coefficients are then calculated to expose the average relative nearness in space of each class with each other class. It would be better to have measures of the flows themselves (as opposed to the spatial patterns of the *results* of the flows), but so far I have been unable to find appropriate data.

29. See: http://people.wku.edu/charles.smith/once/writings.htm#2

30. The methodology produces summary descriptive statistics that can be used to identify changes in the internal structural efficiency of a given subsystemization.