ALFRED RUSSEL WALLACE.

Wallace and the World of Final Causes

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Introduction

Alfred Russel Wallace (1823-1913) is arguably one of the most interesting figures in the history of science. Apart from his prominence in the development of evolutionary biology and biogeography studies, and significant involvement in several other fields of science, he was also known in his time as a scathing social critic and imaginative land tenure theorist – and, not least, one the most vocal supporters of spiritualism. Over the years an array of workers – historians, biologists, geographers, anthropologists, economists and geologists – has been trying to sort all this out, and they have found the

going rough. Wallace was not a conventional thinker, and those who try to pigeonhole his thoughts are bound for failure.

There have been many past failures. In his own time and since, a good number of sources have looked down on his spiritualism as a simple delusion calling into question the rest of his more conventional contributions to science and social science. More recently the attitude has been that there were "two Wallaces": the first a brilliant field investigator and theorist, the other a gullible pawn. Others have looked upon him as a man whose positions on critical issues flip-flopped on several occasions, making his overall views suspect. Even within his own primary field of biogeography, many workers in the late twentieth century came to view him as a dinosaur whose ideas had held back the development of that field (despite the fact that his initial work within that realm directly laid the groundwork for their own!). Still others, with varying agendas, have claimed he was the real originator of the theory of natural selection, and that Darwin stole from him – an accusation made more to the ends of vilifying Darwin than gaining any insight into Wallace's thought. A small present contingent seems to view him as a bloodthirsty murderer who wantonly silenced hundreds of thousands of defenseless animals. Further, there is a selfish effort by today's ID community to portray him as a proto-creationist or ID-er. And to top it off, there is an ongoing questioning of his basically English background by Welsh nationalists who claim him as one of theirs, despite his own referrals to himself as otherwise.

I am confident that all of these problems will be resolved as we become more and more familiar with the man and his writings. But it will not be easy. As Wallace himself noted on several occasions, minds are not easily changed; he saw the matter quite clearly, I think, when he noted that belief is not voluntary: "…Can you really change your opinion and belief, for the hope of reward or the fear of punishment? Will you not say, 'As the matter stands I can't change my belief. You must give me proofs that I am wrong or show that the evidence I have heard is false, and then I may change my belief'?' It may be that you do get more and do change your belief. But this change is not voluntary on your part. It depends upon the force of evidence upon your individual mind, and the evidence remaining the same and your mental faculties remaining unimpaired – you cannot believe otherwise any more than you can fly…"[1] On this basis (and there are plenty of other examples in his writings as well) Wallace's "intelligent conviction" approach may be viewed as a significant step in the development of pragmatic thinking: "… To the mass of mankind religion of some kind is a necessity. But whether there be a God and whatever be His nature; whether we have an immortal soul or not, or whatever may be our state after death, I can have no fear of having to suffer for the study of nature and the search

[1] Letter from Wallace to his brother-in-law Thomas Sims in 1861, reproduced in *Alfred Russel Wallace: Letters and Reminiscences* ed. by James Marchant), 1916 (1975 reprint), on p. 66.

for truth, or believe that those will be better off in a future state who have lived in the belief of doctrines inculcated from childhood, and which are to them rather a matter of blind faith than intelligent conviction."[2]

In this paper I intend to sketch what I believe to be the most fundamental element of Wallace's thought, a belief in final causes. This remained with him his entire adult life, under various guises, and served to unify his thoughts on science, the social environment, and the world of spirit.

What Are "Final Causes"?

Wallace has often been referred to as a teleologist, or theist, or both. Certainly through most of his life he believed that "current events" (such as the execution of natural selection) were ultimately related to larger-scale influences, but it seems to me that neither of these terms describe what he viewed as the processes involved. The "theist" label is mainly directed at his spiritualism beliefs, but here we must be careful, as many or most spiritualists do not adopt a view of reality quite like that of the followers of the great religions. Instead, the "world of spirit" is seen as an extension of the natural world, an extension which is causally linked to the latter, but different from it in not being spatially extended. This, as is plain from all of Wallace's more than one hundred writings on spiritualism, is exactly how he viewed the matter.

The "teleologist" label is a bit more complicated to deal with. The *Dictionary of Philosophy*[3] defines the term "teleology" generally as: "the study of phenomena exhibiting order, design, purposes, ends, goals, tendencies, aims, direction, and how they are achieved in the process of development," but then is more explicit under its entry for "explanation, teleological": "1. Explanation in terms of some purpose (end, goal) for which something is done. 2. Explanation in terms of goal-directed or purpose-directed activity. Usually the goal or purpose is preset or planned. 3. Explaining the present and past with reference to something in the future (a goal, purpose, end, result) that is being striven for or for the sake of which the process takes place. Opposite to mechanistic explanation, which explains the present, and any future event, in terms of conditions prior to it. 4. Explanation in terms of the structures and activities of the parts of a whole being adapted (coordinated, adjusted, fitted suited) to each other toward the fulfillment of the purposes or needs of that whole." Under the entry "causes, Aristotle's four" it defines "final cause" as "*that for the sake of which* an activity takes place; that end (purpose, goal, state of completion) *for which* the change is produced, or for which the change aims (strives, seeks). Its *telos* or *raison d'être*." Other dictionaries and encyclopedias provide similar definitions.

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[2] *Ibid.*, p. 67.

[3] Angeles, Peter A., *Dictionary of Philosophy*. Barnes & Noble Books, 1981.

From these definitions it becomes apparent there is considerable overlap between the more purpose- or will-controlled concept of "teleology" and the "completion" orientation of "final cause." However, teleological explanations are often or usually connected to a first cause, especially the will of God. Wallace would have nothing of first causes, though his position on the possible existence of God was that if He did exist His powers were limited to influencing "lower" beings through natural chains of causality *only*. Any creationist or ID proponent, if wishing to admit Wallace into their camps, needs to come to grips with the fact that he did not recognize the classic Christian model of a God controlling destinies through direct, miraculous intervention, or for that matter any of the other trappings of institutional Christianity such as Heaven and Hell. Wallace did not believe in first causes-based miracles, for example: not because he didn't feel there was adequate evidence for actual events of this sort having occurred throughout history, but instead because he believed such "miracles" devolved from natural causes of which we were still ignorant.

But in the definitions given above there is another "out" on this subject. In the classic setting of the "final cause" idea, the relationship between a sculptor planning out his work, and its actual achievement, is emphasized. The same portrayal could be given for almost anything that is thought out beforehand according to some plan or ideal, but this notion quickly runs into problems when one considers purely physical or biological processes. Even here, however, tolerable examples can be suggested. For instance there is the case of the DNA molecule, which not only guides an individual organism through its full development into an adult being, but in so doing generates an element of the larger ecosystem which serves to help keep that system operating among its many impinging forces. It may be argued that DNA is not much more than a well worked-out and continuously-operating program, but the fact remains that it is a program that only functions properly within a context clearly greater than itself, a fact suggestive of higher levels of control yet.

It is my contention that Wallace was thinking in these general terms throughout his adult life, and that this format permeated his beliefs on evolution, including the evolution of consciousness and social systems. He is possibly the only significant figure ever to have done this, and even for this reason alone his approach is worthy of analysis, even instruction. It should be understood, of course, that he never actually came up with a specific model of how these "final causes" might be operating, but that is not to say that currently we can prove him wrong in his suspicions, or cannot actually extend the agenda to applicable science.

The Development of Wallace's World View: A Model

Wallace's development as a thinker has been treated by a fair number of historians and biographers most of whom, while getting the basic facts straight, have generally been less successful at putting the pieces together into coherent models of his overall world view. As a result there have been frequent allegations of supposed inconsistencies in his writings that I feel are grossly overstated.[4] For example, most observers have expressed a conclusion that Wallace "changed his mind" between 1858 (the "Ternate" essay on natural selection) and 1865/1869, the period of his adoption of spiritualism, on the matter of the applicability of natural selection to human evolution. The conclusion has been, however, that he not only "changed his mind," but actually *reversed* himself on the subject. Built into this observation is the assumption that as of 1858 he already felt that there was no difference between animal/plant evolution and the evolution of higher consciousness, but: (1) there is nothing in the 1858 essay that suggests he thought this at that time (2) he never directly admitted to thinking this in his many later writings on the subject (3) there is nothing in any of his other writings that suggest this. A better conclusion based on the facts is that there was no reversal, and that instead his "opinions on the subject" had merely been "modified." [5]

Wallace's intellectual development was complex, and affected significantly both by the varied events of his life, and the writings of a number of important literary figures. He grew up in a family with little money, and things finally got so bad that he was forced to leave school in his early teens. He became an apprentice, first briefly to a builder in London, and then to an older brother who was forging a successful career as a land surveyor. In his mid-teens he began to take an interest in geology and vegetation and other science subjects, and some years later when his brother moved his operation to South Wales became involved with some of the intellectual groups there, acting as a curator and lecturer in his spare time. In late 1843, during a work slowdown, he moved to Leicester, England, to take a job as an instructor at a private school. He lived there for about fifteen months, during which period he met Henry Walter Bates (1825–1892), whose immersion in entomology caught his attention. It was also during this time he first witnessed demonstrations of mesmerism, and soon found that he himself was able to induce trances in subjects of his choosing. But in early 1845 Wallace's older brother died suddenly, and, left with tidying up his business obligations, he was forced to return to Wales. He soon soured on the work, and concocted a scheme to support himself as a travelling natural history collector. The chosen locale was the Amazon, and in the spring of 1848 he and Bates, who he had enlisted (probably without much difficulty) to accompany him, set out for that location. The rest, as they say, is history.

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[4] By this I mean his philosophy, and not the complaints that his written-down memories of past events in his life were sometimes annoyingly imperfect – which is clear enough.

[5] *Alfred Russel Wallace: Letters and Reminiscences* (Ed. by James Marchant), 1916 (1975 reprint), p. 200. See my *Alfred Russel Wallace: Evolution of an Evolutionist* http://people.wku.edu/charles.smith/wallace/chsarwp.htm for further discussion.

Wallace's early years were impacted by some other associations as well. On originally moving to London, he fell in with some Owenists and soon became attracted to their ideas on social organization and morality. He abandoned conventional religion and became something of an agnostic. A few years later he took part with his brother in surveying work under the Enclosures Act. This experience also left a mark, as he saw first-hand the kinds of miseries it produced among small land-holders.

Meanwhile, he was beginning to read the writings of a number of significant figures across a wide range of subjects. Early on he digested some of the works of Thomas Paine and Robert Dale Owen (son of Robert Owen), eventually coming to the conclusion that self-improvement was closely tied to the matter of intelligent conviction (a somewhat Spinozian point of view, it should be noted). From then on he would put much emphasis on gathering "the facts" before coming to conclusions, a routine that would later make him celebrated for his ability to marshal evidence in favor of particular theories.

By the mid-1840s and his time at Leicester, natural science subjects had begun to dominate Wallace's attention. In 1843 he sent a short essay on telescope optics to a famous early photographer, Fox Talbot, demonstrating the advanced level of his knowledge even at that point. Sometime around then he also encountered and absorbed the writings of Charles Lyell on uniformitarian geology, and at once adopted Lyell's views on a natural reality maintained by slow, inexorable, processes, as distinct from cataclysmic revolutions. In late 1844 or 1845 he read the sensational new book by Robert Chambers (it was originally published anonymously), *Vestiges of the Natural History of Creation*, which espoused a doctrine not only of slow change, but of transmutation (as it was then called) of species. Wallace was an instant convert, apparently, though he recognized in *Vestiges* only the announcement of a theory, and not an exposition of underlying causes. One of the main reasons for the Amazon trip was to collect evidence that, hopefully, would lead to such an understanding.

Other names (Malthus, for example) have also been connected to Wallace's early education, but there are three further ones that may deserve more attention than they have so far received: Alexander von Humboldt, Franz Julius Ferdinand Meyen, and Justus von Liebig. It is well known that Wallace was particularly inspired to travel by the writings of three men in particular: Charles Darwin, W. H. Edwards, and Humboldt (1769-1859), and perhaps most by the last of these. But Humboldt's influence may have extended well beyond this, into the realm of natural philosophy. It must be remembered that during these years, the 1840s, Humboldt was probably the most famous and respected naturalist in Europe (or even the whole world). Wallace had undoubtedly read Humboldt's *Personal Narrative*, an account of his travels in South America at the beginning of the nineteenth century, but it is usually glossed over that Wallace's interest in Humboldt extended to his philosophy of nature in general.

Late in life Wallace reported: "I had been greatly influenced in selecting this work by reading tales of travel, particularly Humboldt's 'Cosmos,' and stories of that great explorer's personal travels."[6] Though it is not certain whether Wallace is remembering the right Humboldt book here, Elwyn Hughes mentions how in a 28 December 1845 letter to Bates Wallace writes he has a "great desire" to read the book, only then recently made available in an English version. Further, an 1852 library catalogue at the Neath Philosophical and Antiquarian Society indicated a copy of the book was purchased for it sometime before that, quite possibly by Wallace, who was a part-time curator and librarian for the organization.[7] Beyond these clues, we know that Wallace at some point read the book, as he quoted words from it in 1871: that "a presumptuous skepticism, which rejects facts without examination of their truth, is, in some respects, more injurious than an unquestioning incredulity."[8] There is thus a very good chance that Wallace got to read the work before he left for South America.

How Humboldt's thought might have influenced Wallace not long after he read *Vestiges* becomes clearer through a couple of quotations from *Cosmos*:

> **"General views lead us habitually to consider each organism as a part of the entire creation, and to recognize in the plant or the animal, not merely an isolated species, but a form linked in the chain of being to other forms either living or extinct. They aid us in comprehending the relations that exist between the most recent discoveries and those which have prepared the way for them."[9]**

> **"The ultimate aim of physical geography is, however, as we have already said, to recognize unity in the vast diversity of phenomena, and by the exercise of thought and the combination of observations, to discern the constancy of phenomena in the midst of apparent changes. In the exposition of the terrestrial portion of the Cosmos, it will occasionally be necessary to descend to very special facts; but this will only be in order to recall the connection existing between the actual distribution of organic beings over the globe, and the laws of ideal classification by natural families, analogy of internal organization, and progressive evolution."[10]**

These remarks – and a dozen more like them scattered throughout the Introduction to the work alone – expose Humboldt as a believer in general principles; of organization coming first, and detail later. Wallace would have been delighted to hear words such as

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[6] *New York Times* 8 October 1911: 8.

[7] R. Elwyn Hughes, "Alfred Russel Wallace; Some Notes on the Welsh Connection." *British Journal for the History of Science* 22, 1989: 401–418, on p. 410.

[8] Wallace, "On the Attitude of Men of Science Towards the Investigators of Spiritualism." In *The Year-book of Spiritualism for 1871* ed. by Hudson Tuttle and J. M Peebles (William White & Co., 1871): 28–31, on p. 30.

[9] *Cosmos*, vol. 1. Harper & Brothers, 1850, on p. 22.

[10] *Ibid.*, p. 43.

these, and coming from a leading light at that. This was the kind of thinking that would expose the workings of great natural processes such as transmutation; at the very least it suggested that change might be related to overarching characteristics of the environment such as climate and landscape. For Wallace it was the first major step toward geography, a study which is indebted to Humboldt as a founding father.

The degree to which Wallace was fascinated by Humboldt is suggested by the presence of Wallace's name on the list of subscribers to the 1846 English language edition of Franz Julius Ferdinand Meyen's *Outlines of the Geography of Plants*. Meyen (1804–1840) was among the most prominent of Humboldt's protégés, and his book contains more than seventy-five mentions of the older naturalist's works. Although Wallace apparently had some trouble obtaining his copy of the book,[11] by 1848 it was probably widespread in major British libraries anyway, and again Wallace very likely read it before leaving for South America.

On examining *Outlines*, Wallace would have found sections titled "On the Conditions of Climate Which Determine the Presence and Distribution of Plants," "On the Conditions by Which the Soil Influences the Station and Distribution of Plants," and "The Distribution of Plants Over the Surface of the Earth." The initial pages mention Humboldt's observations on the latitudinal gradients in plant species numbers, and the final section introduces several themes and challenges that Wallace would later take up in his own work. For example:

> **"The physiognomics of vegetation teach us, that nature, at the creation of plants, has distributed them over the surface of the earth according to certain laws, which are quite unknown to us. We have now learned some of the external causes which place the more developed and nobler forms of vegetation in the hot zones; but we know no cause, why the same species of plants are not always produced in the same conditions of climate."[12]**

Here was a research question worthy of an industrious naturalist!

Justus von Liebig (1803–1873), on the other hand, was a chemist, and a very good one. In one of his later writings Wallace notes: "Living thus almost constantly on the land and among farmers and country people, I soon took a great interest in agriculture. I studied the works of Sir Humphrey Davy and Baron Liebeg, at that time the great authorities on agricultural chemistry. . . . I really believe that at that period of my life I could have passed

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[11] Another letter from Wallace to Bates, dated June 9th, 1846 (Wallace Letters Online, WCP1274), mentions "I have sent up a Guinea to the Ray Society [the book's publisher] but do not know how to get the Books without expense. How do you manage?" Judging from period advertisements, the book apparently became available around May 1846.

[12] *Outlines of the Geography of Plants.* Ray Society, 1846, on p. 99.

a very fair examination in theoretical and practical agriculture."[13] Wallace probably knew Liebig's *Organic Chemistry in its Applications to Agriculture and Physiology*, which had reached English translation from the original German in 1840. Liebig is most remembered for his "law of the minimum," the observation that agricultural yield is directly dependent on the least available critical nutrient, whatever that may happen to be in a particular instance. This "limiting factor" concept was a central element in the development of ecological theory over the next hundred years, and it was likely at the back of Wallace's mind all those years before he hit upon the natural selection concept, which shifted his focus from large-scale environmental controls on evolution to the individual-focused process of selection for adaptive suites.

It appears Wallace encountered *Vestiges* before he read *Cosmos*, and as I state elsewhere:[14]

> **"the dynamic created by this order is an interesting one to consider . . . Both works feature a review of natural phenomena, but *Vestiges* has a more restricted purpose, arguing for the existence of a process of organic evolution. But, even from . . . the quotations given . . . [earlier] one can see that *Cosmos* preaches, at the very least, the existence of 'connections' between natural forms. *Vestiges*, moreover, ultimately is unable to project a process model that could result in organic evolution. Wallace (and just about everyone else) recognized this weakness right away. The author's train of thought was interesting, but on the other hand the book's anonymous publication made it suspect. Humboldt, by contrast, was a world-famous figure as a man of science, and Wallace would have found his words, even if not directly supporting an evolutionary reality, appealing for their visionary worth. The result . . . was a Wallace who in his initial view of cosmology, favored an evolutionary process that worked more from the top down, than from the details of adaptation, up."**

The only other models available to Wallace at that time, moreover, must have been unappealing to him from the start. Creationist logic, whether of an institutional religion type or involving the geological catastrophism many were still espousing, did not interest Wallace. On becoming an agnostic some years earlier he looked disdainfully on the prospect of first causes; beyond this, he had adopted the uniformitarian views of Lyell unreservedly and was not willing to think in terms of major revolutions having taken place in nature.[15] Then there was Lamarckism, in which the changes to an animal's body over its lifetime were posed to be transmitted on to the next generation. Wallace probably learned of Larmarck's ideas through his reading of Lyell, who was one of the few English

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[13] "President's Address." In Report of the Land Nationalisation Society. 1884–5. (Land Nationalisation Society, 1885): 5–15, on p. 15.

[14] Charles H. Smith, *The Real Alfred Russel Wallace. Essays on an Outside-the-Box Thinker* (in press).

[15] Interestingly, Lyell himself initially looked upon biogeographical similarities as possibly being the result of multiple creations.

writers to take much notice of the Frenchman's ideas. But, like many others, Wallace was not impressed with these views, as there seemed to be little if any evidence to back them up.

Later in life Wallace unfortunately had just about nothing to say about his working model of evolution circa 1845 to 1858; neither do his few letters to Bates and others from that period reveal very much. There are, however, a few published writings of his that give us some idea of his leanings at that point. The first comes from his *Travels on the Amazon and Rio Negro*, in 1853, and seemingly harkens back to his reading of Meyen:

> **"It must strike every one, that the numbers of birds and insects of different groups, having scarcely any resemblance to each other, which yet feed on the same food and inhabit the same localities, cannot have been so differently constructed and adorned for that purpose alone. Thus the goat-suckers, the swallows, the tyrant flycatchers, and the jacamars, all use the same kind of food, and procure it in the same manner: they all capture insects on the wing, yet how entirely different is the structure and the whole appearance of these birds!... What birds can have their bills more peculiarly formed than the ibis, the spoonbill, and the heron? Yet they may be seen side by side, picking up the same food from the shallow water on the beach; and on opening their stomachs, we find the same little crustacea and shell-fish in them all. Then among the fruit-eating birds, there are pigeons, parrots, toucans, and chatterers, – families as distinct and widely separated as possible, – which yet may be often seen feeding all together on the same tree; for in the forests of South America, certain fruits are favourites with almost every kind of fruit-eating bird. It has been assumed by some writers on Natural History, that every wild fruit is the food of some bird or animal, and that the varied forms and structure of their mouths may be necessitated by the peculiar character of the fruits they are to feed on; but there is more of imagination than fact in this statement: the number of wild fruits furnishing food for birds is very limited, and the birds of the most varied structure and of every size will be found visiting the same tree."[16]**

Then, three years later, in a treatment of the habits of the orangutan, he states:

> **"Do you mean to assert, then, some of my readers will indignantly ask, that this animal, or any animal, is provided with organs which are of no use to it? Yes, we reply, we do mean to assert that many animals are provided with organs and appendages which serve no material or physical purpose. The extraordinary excrescences of many insects, the fantastic and many-coloured plumes which adorn certain birds, the excessively developed horns in some of the antelopes, the colours and infinitely modified forms of many flower-petals, are all cases, for an explanation of which we**

[16] Wallace, *A Narrative of Travels on the Amazon and Rio Negro* (Ward, Lock, 1889), on pp. 58–59.

must look to some general principle far more recondite than a simple relation to the necessities of the individual. We conceive it to be a most erroneous, a most contracted view of the organic world, to believe that every part of an animal or of a plant exists solely for some material and physical use to the individual, – to believe that all the beauty, all the infinite combinations and changes of form and structure should have the sole purpose and end of enabling each animal to support its existence, – to believe, in fact, that we know the one sole end and purpose of every modification that exists in organic beings, and to refuse to recognize the possibility of there being any other. Naturalists are too apt to *imagine*, when they cannot *discover*, a use for everything in nature."[17]

Wallace's continuing nod to more "recondite" natural forces may in the more general sense be ascribed to, perhaps surprisingly, a general conservatism on his part as to just how much was really known about natural causation during his life. Over his career he returned time and time again to the notion that a particular theory should not be expected to explain everything.[18] And, although he recognized natural selection as a universal "filter" through which all organic change passed, he was keenly aware that little was known about the sources of variation upon which the process acted. As he aged he became more and more fascinated with this matter, despite the fact that he himself remained outside the science on the debate. Still, there seemed to be various kinds of clues available as to the overarching causalities involved.

This is not the place to do full justice to the range and depth of Wallace's appreciations on this matter, but some of these connections, at least, may be mentioned briefly. One well known one is his initial view that vestigial organs were incipient structures; this speaks to his impression that ambient influences on change were in operation. But he didn't stop there, also suggesting that the incipient emergence of mathematical, moral, and paranormal abilities (of spiritualistic mediums, mesmerists and witches) reflected ambient forces extending beyond mere natural selection. So too he treated the connection between beauty and its perception as being relatable to transcendental inertias. As a lesson in this direction he pointed to domestication processes, and how we would not recognize it if we ourselves were experiencing analogous influences; as further evidence of same he pointed to what he interpreted as examples of selective forces being imposed by other higher animals on lower ones. And one must not forget the "balance in nature generated by feedbacks" element introduced in his Ternate essay of 1858. All of these thoughts bear strong traces of the intellectual

[17] Wallace, "On the Habits of the Orang-utan of Borneo" (1856).

[18] See, for example, "Remarks on the Habits, Distribution, and Affinities of the Genus *Pitta*" (1864); "The Limits of Natural Selection as Applied to Man" (1870); "Man and Natural Selection" (1870); "The 'Journal of Science' on Spiritualism" (1885); and "Evolution and Character" (1908).

imprint of von Humboldt: the leaning toward a philosophy supporting what might be termed a "natural systems Bauplan."

Can We Identify a Remote Final Cause?

Wallace's enthusiasm for "remote final causes" notwithstanding, it is fair to ask whether this kind of thinking, focused in the right direction, could actually produce scientific understandings of a useful nature. I don't see why not; nevertheless there would seem to be some limits on how to proceed.

In the 1950s and 1960s a largely new kind of approach to the study of natural and social processes emerged; this became known as "General Systems Theory." Its goal was to identify characteristics of complex systems that might pertain to most or all of them. The movement produced some interesting ideas and a few classic papers[19] and books, but by the 1970s was fading – not necessarily because investigators had entirely lost interest in trying to answer big questions, but because steady progress was being made answering smaller systems-related questions in fields such bioengineering, artificial intelligence, and robotics. In short, investigators retreated to more conventional, reductionist approaches to answer more particular questions. Yet in recent years attempts to answer the "big questions" seem to be on the ascendency again. A brief description of a couple of these seems in order here.

In the 1990s an engineer named Adrian Bejan began to promote a model of organizational tendencies he termed "constructal theory." The essence of this theory is that all things in nature that arise spontaneously evolve internally in such a manner as to facilitate flows of energy – that is, to improve the ratio of mass moved within the system to the amount of energy needed to move it. Bejan has devised ways of looking at structures undergoing such organization, and provided many examples.[20] From one perspective, this might be regarded as a model of final causes, because all systems are supposed to undergo such developments as a simple matter of physics that makes their directional development inevitable.

Nevertheless, Bejan's model has found limited support, not because it seems to be unreasonable *a priori*, but instead because its formulation is rather vague. Many of its most crucial elements have not been reduced to first principles, with the result that its key concepts related to flow and access remain poorly defined. I believe one of its most severe problems is its lack of integration of the notion of constraints into the model; i.e., it embraces a self-organization model that does not recognize a generalized

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[19] Most notably, Magorah Maruyama, "The Second Cybernetics: Deviation-Amplifying Mutual Causal Processes." *American Scientist* 51, 1963: 164–179.

[20] Bejan, Adrian, *Design in Nature: How the Constructal Law Governs Evolution in Biology, Physics, Technology, and Social Organization*. New York: Doubleday, 2012.

understanding of restrictions on complexification, and especially the relationship of system function to the fact of existing as a spatially-extended reality.

The standard reductionist model begins with a spatial setting "within which" things happen. The reality of space itself, and how spatial extension might be fundamental to the organization and interactions of all things, is usually ignored or assumed. However, it is entirely possible that space itself is emergent in the things we usually merely think of as "being in it." A true final cause may lie lurking in the rules of emergence, and how this affects the evolution of any complex system.

In the 1980s I began to investigate this concept, and soon came upon the writings of Benedict de Spinoza (1632–1677), the great Rationalist philosopher. In his *Ethics* he deduces the plan of nature, a plan which recognizes an essential similarity of organization up and down the natural hierarchy through the operation of two fundamental attributes, "thought," and "spatial extension." These "attributes," however, are not of the kind we now associate with particular aspects of natural systems, but are instead what might be termed "rules of order" that apply to the organization of all of them. After some years of considering the matter, I came to a model I have been trying to develop ever since.

The key to this model is the notion that all natural systems might *subsystemize* in a manner common to them all, and do so in a way that *itself* constitutes physical, extended space. Thus within every natural system, large and small, there might be an exchange of energy and information that satisfies the integrity of the system, and generates space as it does.[21]

To investigate this idea I have employed both simulation techniques and empirical analyses of actual systems. The simulations were aimed at determining whether the input-relations of a mathematical system might correspond to a spatial projection of same. Many thousands of matrices with dimensions of n = 3,3 through 7,7 were filled with random numbers, then entropy-maximized (through an operation known as double standardization, or bistochastization) to investigate whether the output corresponded to a three-dimensional, spatial, output. It turned out that only matrices of dimension 4,4 could produce such output, and at a rate of less than two percent (depending on the exact details of the constitution of the matrix) of configurations tested. So, for example, a 4 x 4 matrix containing a set of random numbers might double-standardize to a result of:

[21] More details on this theory cannot be introduced here, but I have both published matter and website pages that provide further discussion. See Charles H. Smith & Megan Derr, "'In Space' or 'As Space': A New Model." Life (MDPI) 2, 2012: 243–254; and Charles H. Smith, "A Theory of Spatial Systems," http://people.wku.edu/charles.smith/once/writings.htm#2

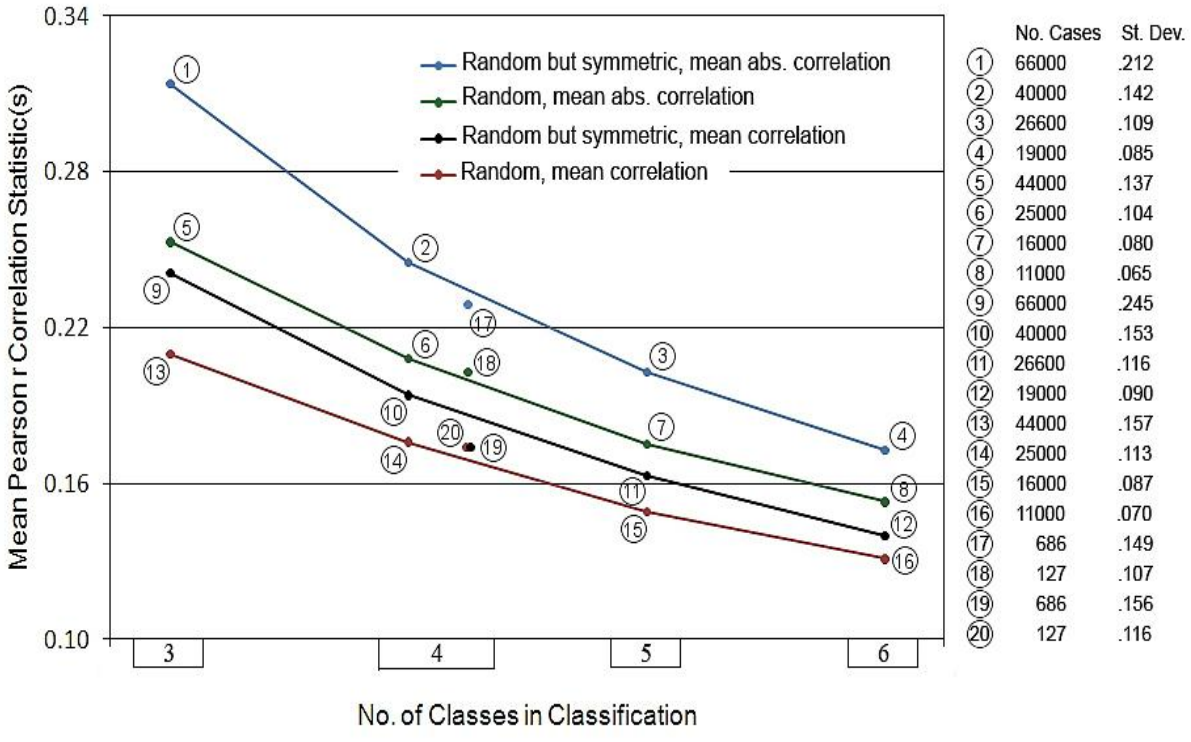
1.2344	-1.0426	-0.9238	0.7320
-0.9238	1.2344	0.7320	-1.0426
-1.0426	0.7320	1.2344	-0.9238
0.7320	-0.9238	-1.0426	1.2344

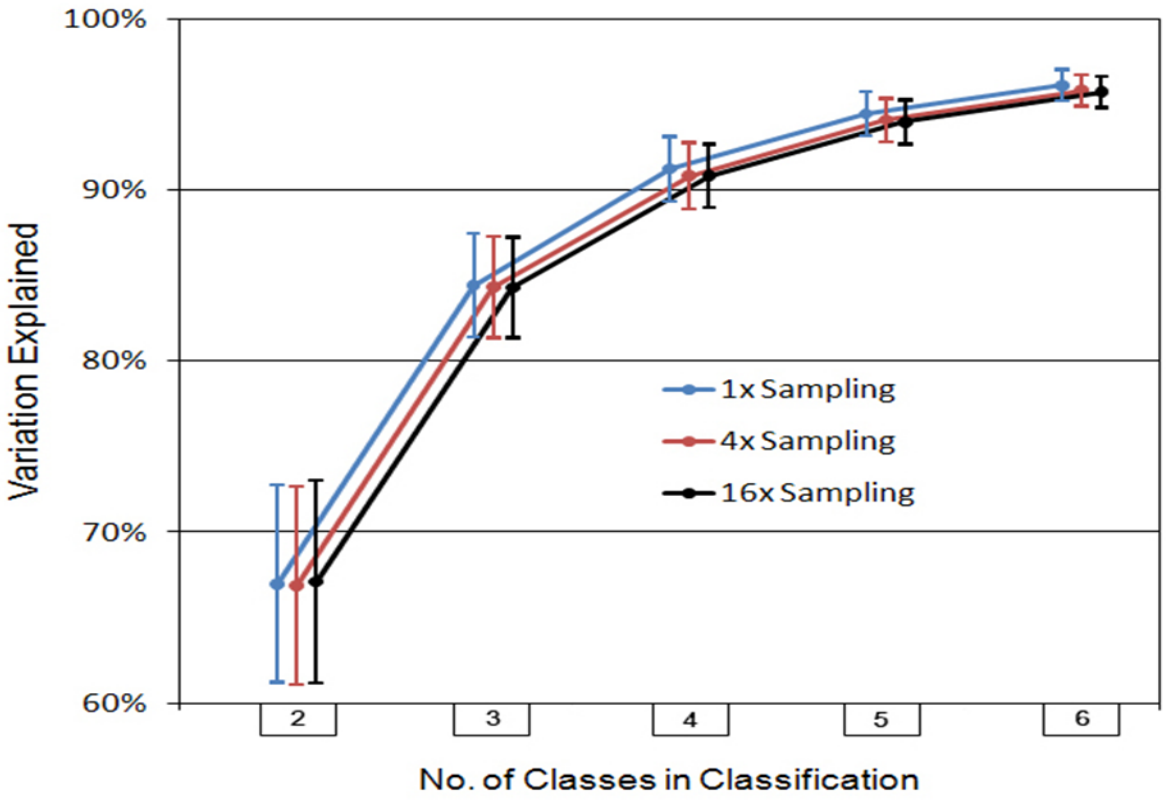
Or it might double-standardize to:

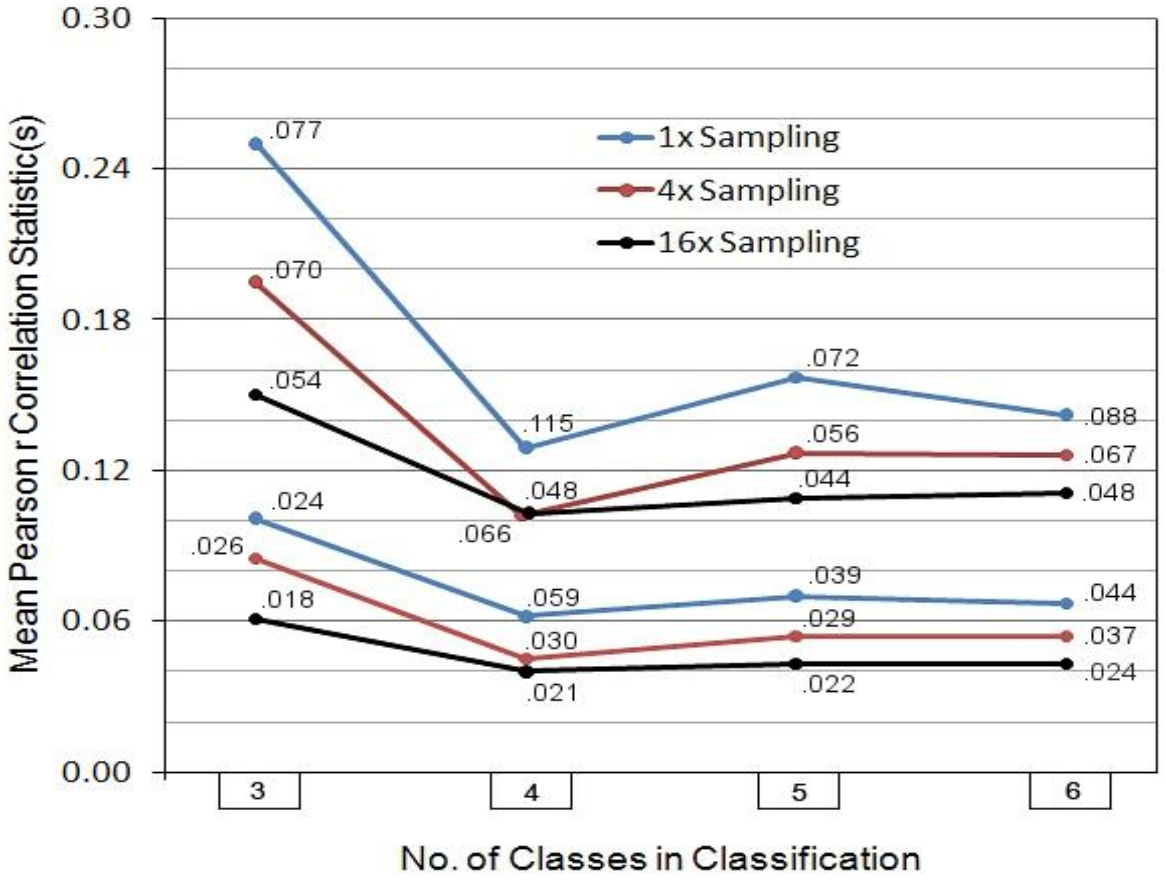
1.2344	-0.9238	-1.0426	0.7320
-0.9238	1.2344	0.7320	-1.0426
-1.0426	0.7320	1.2344	-0.9238
0.7320	-1.0426	-0.9238	1.2344

It turns out that only the second set of results, involving symmetric output, will project an unambiguous Euclidean three-dimensional space. This approach was extended to simulations of (grouped) random patterns on two-dimensional and three-dimensional surfaces. Generally speaking, successful three-dimensional projections were more frequent than for the unconstrained random numbers.

I then began to apply the same method to study group spatial patterns in some real world structures. In a study of topographic patterns within thirty-one stream basins in the Commonwealth of Kentucky, thirty of the basins passed the spatial projection test (with the last one only narrowly missing). Just as importantly, a secondary statistic used to describe the degree of redundancy of structure within each matrix representation of the basins showed a clear affinity with the four-subsystem model, as shown below.




100%
90%
80%
70%
60%
Variation Explained
1x Sampling
4x Sampling
16x Sampling
2
3
4
5
6
No. of Classes in Classification


0.30
0.24
0.18
0.12
0.06
0.00
Mean Pearson r Correlation Statistic(s)
1x Sampling
4x Sampling
16x Sampling
.077
.070
.054
.115
.066
.048
.072
.056
.044
.088
.067
.048
.024
.026
.018
.059
.030
.021
.039
.029
.022
.044
.037
.024
3
4
5
6
No. of Classes in Classification

The remarkable thing about the third graph above is that it shows that the simulations notwithstanding, in the setting of an actual set of stream basins there is a decided minimization of the internal redundancy measure at the four-class definition of the systems. Thus, there is apparently something about the four-class solution that is special; that is, that may be related to an actual organizational influence, and not merely a statistical artefact. Are we looking at a final cause in action? Would Wallace be surprised?

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