Perfect Adaptation and Teleological Explanation: Approaches to the Problem of the History of Life in the Mid-nineteenth Century

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1

Naturalists in the mid-nineteenth century commonly believed that adaptation is perfect. In this they were guided by a number of considerations, not the least of which was their respect for the opinion of the greatest biologist of the first third of the century, Georges Cuvier. Cuvier held that every type of organism is perfect, in that its parts are functionally coordinated and the whole and all its parts are constructed in the best possible manner for the functions they are to perform and for the situation in which the organism is to live. The idea of perfect adaptation, in Great Britain especially, was a cornerstone not only of biology, but of natural theology as well. The perfect adaptation of structure to function and of the whole organism to its environment was evidence of purposeful design and hence of an Intelligent Creator. It was further supposed by many naturalists—and in this, again, they followed Cuvier—that purpose is a sufficient explanation both of organic structure and of the succession of organisms through geological time. The eye is constructed as it is because it was intended (the natural theologian might say "the Creator intended") that it should serve the function of seeing, and the

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structure of the eye is the best conceivable structure for that purpose. Similarly, fish, reptiles, and mammals appeared on the earth in succession because these classes were perfectly suited for environmental conditions which appeared successively.

This sort of explanation, which accounts for structure and succession by reference to purposes, or final causes, is generally called teleological. As it was used by naturalists in the mid-nineteenth century, it depends on the idea of perfect adaptation. One is not likely to explain the structure of the eye by reference to its functions if it only imperfectly performs them. Nor, from the point of view of natural theology, would the imperfect fulfillment of the purposes for which the eye's structure was intended reflect well on the intelligence, benevolence, or skill of the Creator. But though such teleological explanation requires belief in perfect adaptation, the converse is not true: belief in perfect adaptation does not require that one explain organic structure and succession teleologically. It is possible to hold that organisms are perfectly adapted because they are parts of a natural order established by God, but to believe also that the components of that order are to be explained by natural laws, not by reference to final causes.

The distinction between the idea of perfect adaptation, on the one hand, and teleological explanation, on the other, is of particular importance for our understanding of the biological thought of the mid-nineteenth century. Darwin's theory of evolution, based on competition and less-than-perfect adaptation, undercut the idea of purposeful design as no previous evolutionary theory had done. But it would be wrong to conclude from this that Darwin also singlehandedly undermined teleological explanation, for many biologists had already rejected the latter when the Origin of Species appeared. Although the idea of perfect adaptation was virtually unchallenged before 1859, this was not true of teleological explanation. In the three decades before the publication of the Origin of Species, many biologists who continued to believe in perfect adaptation repudiated teleological explanation in favor of alternative approaches to the problems of organic structure and organic succession.

While both those who made the shift away from teleological explanation and those who did not generally believed in perfect adaptation, they conceived of it differently. They held divergent views on the relationship of organisms to their environments and on the connection between the history of life and the history of the earth. The teleologists believed that perfect adaptation implied a very close connection between the organic and inorganic worlds. Their theories of organic succession were therefore inseparable from geological theory. Their conceptions of the history of life depended directly on their conceptions of the history of the earth, because they viewed the successive appearance of different forms of life as the perfect adaptation of new organisms to changing environmental conditions. Those who rejected teleological explanation denied that perfect adaptation implied any such close connection between the organic and inorganic worlds. They said that the same type of organism might be perfectly suited for many different environmental conditions and many different types suited for the same conditions. This left them free to develop specifically biological theories of organic succession which were independent of geologists' views on the history of the earth.

Because of this difference in interpretation of perfect adaptation, the shift away from teleological explanation, important in its own right, takes on added significance: it provides us with a key to the maze of pre-Darwinian theories of the development of life. It allows us to see that beneath the superficial similarities between the progressionist theories of Adam Sedgwick and William Buckland, on the one hand, and Richard Owen and Louis Agassiz, on the other, there lie fundamentally different views of the history of life. It shows us that the progressionism of Sedgwick and the nonprogression theory of Lyell are products of a single way of looking at the problem of organic succession. And it helps explain why those who, in the second half of the century, thought and wrote about the development of life on the earth found Owen's and Agassiz's ideas on the subject more interesting and suggestive than those of Sedgwick, Buckland, or Lyell. In this paper I intend first to examine the shift away from teleological explanation and then to sketch briefly how recognition of the shift gives us a useful means of distinguishing among the theoretical views of mid-nineteenth-century naturalists, a means which may serve as a suitable replacement for the traditional evolutionist-creationist dichotomy, which has perhaps obscured more than it has explained.

II

In his discussion of morphology, which he called "the most interesting department of natural history" and, indeed, "its very soul," Darwin in the Origin of Species came down solidly on the antiteological side of the debate which had been carried on intermittently since the time of Cuvier and Étienne Geoffroy Saint-Hilaire. The structural similarities between plants and animals of the same class, he argued, are to be explained not by reference to the functions which the structures are intended to serve, as Cuvier had thought, but by reference to a common plan of organization or general pattern which existed in the ancestor of the class. It is the existence of this general pattern, Darwin said, which makes intelligible the homologies between the hand of man, or of the mole, the leg of the horse, the paddle of the porpoise, and the wing of the bat. To try to explain these similarities of pattern "by utility or by the doctrine of final causes" is hopeless, Darwin said; and he added: "the
hopelessness of the attempt has been expressly admitted by Owen in his most interesting work on the "Nature of Limbs."**6

Darwin would have provided his readers with a more accurate picture of the state of contemporary opinion on teleological explanation had he written instead: the hopelessness of the attempt has been insisted upon by Owen. Richard Owen's *On the Nature of Limbs*, published in 1849, was not, as Darwin implied, a teleologist's admission of defeat. Rather, it was an extended argument against teleological explanation in biology. That there was design in nature, Owen firmly believed. But he did not regard design as a sufficient explanation of organic structure.

Owen stood on its head the machine analogy so dear to British natural theologians, who likened the organism to a machine, which, with its parts adapted to particular purposes, shows evidence of contrivance, and therefore of a contriver. The structure of each part is explained by the function which the contriver has designed it to perform. Owen pointed instead to a fundamental dissimilarity between the engineer's machines and the Creator's organisms. In keeping with the material conditions of nineteenth-century England, he abandoned Paley's example of self-propagating watches in favor of railroad engines and other machines of the industrial age. Man, he said, has made numerous devices for moving on and through the earth, sea, and sky. In doing so, he has not made them according to any general pattern or plan, but has adapted them directly to their functions. As a result, there are only the remotest analogies between balloons, boats, Stephenson's locomotive, and Brunel's tunneling machinery. The teleologist, Owen said, who wishes to explain organization solely in terms of adaptation to function, should expect to find no greater similarity among the instruments by which various animals traverse these different elements—among, for instance, the forelimbs of man, horse, bat, mole, and dugong. But, as every anatomist knows, these limbs, which serve such varied functions, are built according to a single pattern. The goal of the comparative anatomist, Owen said, is to discover the law governing this conformity to pattern. In the search for such law, final causes give us no clue. They are, as Bacon declared, like vestal virgins, "barren and unproductive of the fruits we are labouring to attain."**7

*On the Nature of Limbs* is by no means an isolated example of the rejection of Cuvierian teleology in England. Indeed, it is a rather late statement of a position adopted by Owen and a number of other British biologists during the 1830s. An early instance of the shift away from teleological explanation is to be found in so unlikely a spot as one of the Bridgewater treatises. The authors of the Bridgewater treatises were commissioned to illustrate design in nature, and in most cases they frankly adopted teleological explanation as well. Charles Bell's treatise on *The Hand* is typical. Bell rejected Geoffroy in favor of Cuvier and insisted that the only principle which should be employed in

explaining animal organization is the "principle of adaptation."**8 However, in the same year as Bell's work on *The Hand* was published, 1834, Peter Mark Roget brought out the treatise on *Animal and Vegetable Physiology*, in which he suggested that some organic structures cannot be explained solely by their functions, but instead must be referred to a general pattern. Nature, he said, has laid down certain great plans of functions and, in accordance with them, has established general structural patterns for each class of animals. More specialized structures, which carry out the subordinate functions in each species, are not adapted directly to their special functions, but are governed and limited by the general pattern, or type, on which the species is modeled. The student of animal organization must recognize not only adaptation to function—as the teleologist assumed—but also a "law . . . of conformity to a definite type."**

Two years later Martin Barry argued, somewhat more forcefully, that form, rather than function, was the more fruitful guide to the solution of the most profound problems in natural history. Like Roget, Barry stopped short of declaring the absolute priority of the study of structure:

*It has been usual [he said] to regard organic structure as manifesting design, because it shows adaptation to the function to be performed. It has also been suggested, that function may be equally well considered as the result of structure. And, truly so it may. Yet perhaps we are not required to shew the claim of either to priority; but may consider both structure and function,—harmonizing, as they always do,—as having been simultaneously contemplated in the same design."**

Having in this fashion made his bow to the reigning orthodoxy, Barry went on to argue throughout the rest of his article that the investigation of animal organization must focus on structure and development. Adaptations to particular functions merely confuse the naturalist, he said. The deepest insight into nature is to be gained by studying the underlying unity of structure while ignoring the diversity of adaptive features.**

Barry's arguments were incorporated by Owen into his Hunterian Lectures of 1837, where they formed part of a critique of the teleological approach to comparative anatomy.** A more important critique was that of William B. Carpenter. In a review article in 1838 and again in his widely read textbook of physiology, first published in 1839, Carpenter argued that teleology was not the proper method for the biologist. Carpenter was responding to William Whewell's treatment of physiology in his *History of the Inductive Sciences*. In his Bridgewater treatise on *Astronomy and General Physics*, Whewell insisted that teleological explanation is inappropriate in the physical sciences. Final causes are to be excluded from the investigations of the physical philosopher, he said. Only after the enquiry into the laws governing a phenomenon is complete may the purpose of the phenomenon be considered, at which time
the fitness of the means for the end appears as irrefutable proof of the existence of an intelligent Creator. But when in his *History* he came to discuss physiology, Whewell characterized Geoffroy’s rejection of the teleological method as the “superstition of a false philosophy” and urged that it is both proper and necessary to assume “the existence of an end as our guide in the study of animal organization.”

In insisting on the necessity for teleological thinking in physiology, Whewell was following Kant, but with one difference. Kant had argued that the existence of means apparently designed for particular ends could not be used to prove the existence of God, for it is not possible to know that such arrangements could not be produced by the operation of mechanical laws. Whewell, in accordance with the tenets of British natural theology, believed that adaptation to purpose was indeed evidence of creative intelligence. On the method of the biological sciences, however, there was no disagreement. Whewell quoted Kant with approval:

It is well known that the anatomists of plants and animals, in order to investigate their structure, and to obtain an insight into the grounds why and to what end such parts, why such a situation and connexion of the parts, and exactly such an internal form, come before them, assume, as indispensably necessary, this maxim, that in such a creature nothing is in vain, and proceed upon it in the same way in which in general natural philosophy we proceed upon the principle that nothing happens by chance. In fact, they cannot live free themselves from this teleological principle as from the general physical one; for as, on omitting the latter, no experience would be possible, so on omitting the former principle, no clue could exist for the observation of a kind of natural objects which can be considered teleologically under the conception of natural ends.

Kant argued not only that the teleological method is necessary in biology, but that its necessity sharply distinguishes biology from the physical sciences. J. D. McFarland explains that for Kant “any objective explanation must be a mechanical one, and since organisms cannot be explained mechanically, they can never be given an objective explanation.” Whewell, who was well aware of the great strides which had been made in the understanding of organic nature since Kant wrote, was not willing to go so far. But his treatment of physiology makes clear that he assigned it a status inferior to that of physics.

To this Carpenter, reviewing Whewell’s *History*, objected strongly. Physiology, he declared, has the same claim to be considered an “inductive science” as does physics or astronomy. The problem with physiology is not that it is essentially different from physics, but that in physiology it is so much more difficult than in physical science to discover mere facts, much less to derive laws from them. Whewell’s examples of great “doctrines” which the teleological method had established—such as the circulation of the blood—are not doctrines, or “laws,” at all, Carpenter said. They are rather some of the facts whose discovery is necessary before general laws can be formulated. “Were we able to ascertain facts regarding the changes which take place in the interior of the living body as easily as the astronomer observes the place of a planet, or the chemist the decomposition of a salt, there is no reason whatever to prevent these facts being generalized in the same manner and to the same degree with those of the physical sciences.”

Carpenter went on to criticize Whewell’s discussion of the dispute between Geoffroy Saint-Hilaire and Cuvier. Geoffroy’s rejection of final causes, Carpenter said, and his statement, “I ascribe no intention to God,” are no more irreligious than Whewell’s prescription of method for the physical sciences: “we are not to assume that we know the objects of the Creator’s design, and put this assumed purpose in the place of a physical cause,” Whewell had written. Were biologists to follow Whewell’s advice and adhere to the method of final causes, as practiced by Cuvier, their science would be limited to the discovery of facts, while general laws would be lost from view:

The philosophic Physiologist, who is not deterred by the clamour of bigotry and prejudice [Carpenter said], will follow precisely the same course [as the physical philosopher]. The adaptation which he discovers in particular instances may well serve both to awaken his curiosity, and to lead him to suspect a pre-existing Design. But he will obtain a much more elevated view of the nature of Creative power if he carry his enquiries further. He must disregard for a time, as in physical philosophy, the immediate purposes of the adaptations which he witnesses; and must consider these adaptations as themselves but the results or ends of the general laws for which he should search.

Carpenter’s statement of the method of physiological research expresses well the views of those biologists who were dissatisfied with the method of final causes. With few exceptions they believed that there was design in nature. They accepted as a general fact the admirable adaptation of structure to function. At times they were even willing to explain particular adaptations in functional terms. But they held that the physiologist was not to rest content with the discovery of purposes. His goal was rather to find the “general laws” which governed both structure and its adaptation to function.

III

In the same years which saw Roget, Barry, Owen, and Carpenter move away from the teleological explanation of organic structure, there occurred a corresponding shift in explanations of organic succession. During the 1830s and 1840s most British geologists, and the older biologists, such as Charles
Bell, advocated a teleological explanation of the development of life on the earth. Central to this explanation was the "principle of adaptation," which stated that every organism is perfectly adapted to the situation which it occupies in the economy of nature. As new environmental conditions have arisen during the history of the earth, new species, specially suited for these conditions, have been created by some unknown means. The succession of organisms on earth is thus dependent on the development of the earth itself.

This explanation had the support of numerous prominent naturalists, among them the progressionist geologists and the uniformitarian Charles Lyell. The teleological interpretation of perfect adaptation is most clearly displayed in Lyell's writings, for he made it into a central element in the antievolutionary strategy of his Principles of Geology.74 Later, when he began to reconsider his stance on evolution, Lyell set down in his private species journals an admirably explicit statement of the assumptions on which he and his fellow geologists had worked. For him, perfect adaptation implied environmental determinism, a determinism in which the "necessity" of the relationship between organism and environment lay in the goodness of God. Of all the ways, Lyell said, in which the Creator might adapt a new organism to the conditions under which it and its descendants are destined to live, it may be that one way "is preferable to all others." In this case, the Creator will always choose that one. For every given set of environmental conditions, there will be called into existence that organic form which is the best suited of all possible forms for those conditions. Since only one form can be the best of all possible, eternal conditions determine which forms are created. "What is here called necessity," Lyell said, "may merely mean that it pleases the Author of Nature not simply to ordain fitness, but the greatest fitness." 75

Lyell no doubt recognized that it was not possible to demonstrate in any satisfactory fashion that a given species is the best possible for the conditions in which it exists. But he thought it could be proved that a deterministic and uniform law of adaptation is at work by showing that similar conditions always "produce" similar forms of life.76 For support he turned to the study of geographical distribution, and in particular to the writings of De Candolle. It was well known, and De Candolle emphasized that widely separated regions of the earth which have similar climates are not generally inhabited by the same species of plants and animals. It would probably not be difficult, he said, to find two points in the United States and Europe, or America and equinoctial Africa, in which the same external conditions exist—the same temperature, elevation, soil, and humidity—but in which all, or nearly all, the plants are different. Such facts were not at all favorable to Lyell's environmental determinism. But De Candolle went on to say that there is nevertheless a strong analogy of form between inhabitants of regions in which external conditions are similar. If the species are not the same, the genera often are.76 It was in this statement that Lyell found justification for his proposition that similar conditions always produce similar forms of life.

De Candolle himself concluded that the difference in the species which inhabit areas with similar conditions indicates that some factors, besides adaptation to conditions, are involved in determining the distribution of organisms.87 Although Lyell quoted De Candolle's opinion on this point, he did not accept it. Lyell believed that the "principle of adaptation" alone could account for all the phenomena. De Candolle wrote that "a portion of the phenomena of the distribution of plants in the different countries appears to relate to the appreciable influence of temperature; but there remain some facts which elude all existing theories because they relate to the very origin of organized beings, that is to say, to the most obscure subject in natural history."88 Lyell, on the contrary, said that if similar conditions do not produce the same species, this is due not to any additional, as yet unknown, biological laws, as De Candolle seemed to suggest, but to the fact that the climates, though similar, are not identical. The environmental conditions which, in different regions, or at different geological periods, determine the existence of particular species, are too complex ever to be precisely duplicated, he said. But they may be so nearly duplicated as to produce the same genera in different regions or at different times in the past and future. For Lyell the teleological explanation of organic succession was sufficient.89

It is usual to stress the differences, which are considerable, between the views of Lyell and those of most of his contemporaries.90 Lyell argued that the history of the earth is cyclical and that the history of the organic world is a parallel series of cycles: when the current cycle of change in the inorganic world is completed, and the climate of an earlier geological age returns, then iguanodons, ichthyosaurs, and pterodactyls, which were perfectly suited to the ancient climate, will again inhabit the earth, he thought.91 Adam Sedgwick, William Buckland, and Henry De la Beche, on the other hand, supposed that the earth has undergone a directional rather than a cyclical development and that at successive geological epochs it has been suited to the existence of "higher" forms of life.92 On the questions of directional development and organic progress, there was indeed a fundamental disagreement between Lyell and most of his colleagues. But on the question of the explanation of organic succession there was an equally fundamental agreement. The progressionism of the majority of British geologists was built on the same foundation as Lyell's nonprogressive cycles of life—the principle of perfect adaptation to changing conditions.

The progressionists were as little willing as Lyell to admit the insufficiency of the teleological explanation of the history of life. Progress, they insisted, depends not on some biological law of development, but on progressive
changes in the environment. "There have been successive creations as new conditions have arisen, so that every place capable of sustaining life has been filled by that fitted for it," wrote De la Beche. Animals and plants, Buckland said, "were constructed with a view to the varying conditions of the surface of the earth, and to its gradually increasing capabilities of sustaining more complex forms of organic life, advancing through successive stages of perfection." And Sedgwick insisted that organic succession was to be explained not by some biological law but by "creative power" adapting new forms of life to gradually changing conditions. The theory of the progressivists probably cannot appropriately be called, as Lyell's can, environmental determinism. In essentials, however, their theory and Lyell's are identical.

IV

In the middle decades of the nineteenth century, a number of biologists rejected the geologists' interpretation of perfect adaptation in favor of an alternative approach which allowed them greater freedom in constructing theories of organic succession. While accepting perfect adaptation as an important phenomenon, they ignored it in their attempts to formulate specifically biological laws of the development of life. Owen, Carpenter, and Louis Agassiz, among others, were no more content with the teleological explanation of organic succession than they were with the teleological explanation of organic structure. Carpenter, in 1839, suggested that "those who have dwelt most upon this adaptation of the structure of living beings to the external conditions in which they exist, appear to have forgotten that these very conditions might be regarded, with just as much propriety, as specially adapted to the support of living beings." 28

In one sense, Carpenter's charge is untrue. Lyell and the progressivists viewed the organic and inorganic worlds as mutually adapted, as two halves of one harmonious plan. But for all practical purposes, Carpenter was right. The geologists failed to see, or were unwilling to admit, the implications of the possibility that the earth might be "specially adapted" for the existence of living beings. They did indeed believe that external conditions were designed with the organic world in mind. But they supposed that the external conditions at any period, though known beforehand by God, are the product of geological forces and laws, not of special adaptation to the living beings then or about to be in existence. The fitness of the conditions for the organisms results from the fact that the development of the inorganic world was planned by the Creator so as to be suitable for the successive forms of life. Organisms, on the other hand, were supposed to be "specially adapted" to conditions which gradually arose during the earth's history. The geologists always treated geological change as primary and organic change as dependent upon it. In their eyes there was a strict parallel between the history of the earth and the history of life, and designed adaptation to conditions was the only acceptable explanation of the organic half of the parallel. 28

For Carpenter, adaptation was no explanation at all, but was rather the result of laws which remained to be discovered. What he was saying is that it is possible that events in the organic world, though known beforehand by God, are the result of biological forces or laws, not of special adaptation to conditions. It is as reasonable to suppose that biological change is primary, and that geological changes are "specially adapted" to it, as the reverse. And since one supposition is as reasonable as the other, the notion of special adaptation has no explanatory value in either geology or biology. The student of living beings, like the student of external conditions, must ignore adaptation and search instead for the underlying laws and forces which produce it.

In their writings in the 1840s and 1850s Owen and Agassiz adopted positions similar to Carpenter's. Agassiz, in his Essay on Classification, expressed most clearly the biologists' broader interpretation of perfect adaptation. Like Carpenter, Agassiz criticized in almost the same stroke of the pen both the method of final causes in comparative anatomy and the teleological explanation of organic succession. The explanation of organic structure in terms of the functions which the organs are intended to serve is the basis for most general works on comparative anatomy, he said, "and yet there never was a more incorrect principle, leading to more injurious consequences, more generally adopted." As proof of the inadequacy of the functional approach, Agassiz cited the fact that throughout the animal kingdom identical functions are performed by a great variety of organs. 29

Agassiz argued that similar facts made untenable the teleologists' narrow interpretation of perfect adaptation to external conditions. Adaptation is indeed perfect, he said, and its perfection is evidence of creative wisdom and power. But there does not exist any strict relationship between particular organisms and particular external conditions of existence. On the contrary, organisms exhibit an extraordinary independence from the influence of physical agents. Much of the first chapter of Agassiz's Essay (some two hundred pages) is devoted to refuting environmental determinism, and this is the sole aim of sections two and three—"Simultaneous existence of the most diversified types under identical circumstances" and "Repetition of identical types under the most diversified circumstances." The Creator, Agassiz insisted, has adapted many different types of organisms to the same conditions and has adapted the same type to many different conditions:

As much as the diversity of animals and plants living under identical physical conditions shows the independence of organized beings of the medium in which they dwell, so far as their origin is concerned, so independent do they appear again of the same influences when we consider the fact that identical types occur everywhere upon
earth under the most diversified circumstances. If we sum up all these various influences and conditions of existence under the common appellation of cosmic influences, or of physical causes, or of climate in the widest sense of the word, and then look around us for the extreme differences in that respect upon the whole surface of the globe, we find still the most similar, nay, identical types ... living normally under their action. There is no structural difference between the herring of the Arctic and those of the Temperate zone, or those of the Tropics and those of the Antarctic regions; there is none between the foxes and the wolves of the most distant parts of the globe. Moreover, if there were any, and the specific differences existing between them were insisted upon, could any relation between these differences and the cosmic influences under which they live, be pointed out, which would at the same time account for the independence of their structure in general? Or, in other words, how could it be assumed, that, while these causes produce specific differences, they at the same time produce generic identity, family identity, ordinal identity, class identity, typical identity? Identity in every thing that is truly important, high, and complicated in the structure of animals, produced by the most diversified influences, while at the same time these extreme physical differences, considered as the cause of the existence of these animals, produce diversity in secondary relations only! What logic!

Does not all this show, on the contrary, that organized beings exhibit the most astonishing independence of the physical causes under which they live,—an independence so great that it can only be understood as the result of a power governing the physical causes themselves, as well as the existence of the animals and plants, and bringing all into harmonious relations by adaptations which can never be considered as cause and effect?24

Agassiz denied absolutely the teleologists’ interpretation of perfect adaptation. Environmental determinism and the explanation of organic succession in terms of the development of the inorganic world were, in his eyes, absurd. The facts simply were incompatible with the presumed parallel between the history of the earth and the history of life.25 The rejection of teleology secured the independence of biological theory from geology. Once the teleological explanation of succession was abandoned, theories of the organic world were no longer tied to any geological system, whether it be Lyell’s cycles or the progressionists’ directional development. The history of life could be treated on its own terms. Biologists recognized that organisms are well suited for the conditions under which they exist—if they were not, they could not exist at all—but they denied that this fact contributes to our understanding of organic succession. Instead of supposing that there exists a fixed relationship between organic form and physical conditions, biologists looked for relationships among the successively appearing forms of life themselves. They attempted to account for the history of life not by the “principle of adaptation” but by morphological and paleontological laws.

Not all of the morphological and paleontological laws which were proposed in the 1840s and 1850s had lasting or even temporary value. The classic example of one which added nothing to naturalists’ understanding of organic succession is Edward Forbes’s law that “the distribution of organized beings in time” is a “manifestation of the relation of Polarity.”44 Forbes’s law is significant chiefly because it called forth a reply from Alfred Russell Wallace, “On the Law which Has Regulated the Introduction of New Species,” which is of interest in light of Wallace’s subsequent achievements and for its role in inducing Darwin to begin writing his large book on natural selection. On the other hand, some of these laws made undeniable contributions to theoretical paleontology and evolutionary speculation.45 Probably the best known of these is Agassiz’s law that there is a correspondence between the structural relations of existing organisms, the stages of their embryological development, and their order of succession in geological time.46 Although it has been much criticized, especially by historians of embryology, Agassiz’s law exerted considerable influence on biological thought both before and after 1859. Even Huxley, who controverted Agassiz’s law in the 1850s and opposed Agassiz on the question of evolution in the 1860s, admitted that Agassiz had “help[ed] the cause he hated.”47

Owen and Carpenter also proposed a law of development based on morphological and embryological concepts. They argued that earlier forms of life had a more general, or less specialized and complex, organization than plants and animals which came into existence at subsequent periods and that the earlier forms were often intermediate in character between groups which appeared later. Their law, they said, was a paleontological analogue of von Baer’s embryological law that development always proceeds from the more general to the more special form.48 Owen’s and Carpenter’s law of organic succession embraced the idea of divergence and a new conception of progressive specialization, both of which were to become important in paleontology and general evolutionary thought after 1850.

The ideas of Agassiz, Owen, and Carpenter exerted an appreciable influence on most of the evolutionists of the second half of the nineteenth century—Robert Chambers, Baden Powell, Wallace, Darwin, Spencer, Haeckel, Huxley, and the paleontologists of North America and the continent, as well as of Great Britain. Their laws contributed significantly to the picture of the development of life on the earth which began to emerge in the 1840s and rapidly gained acceptance after 1859. The teleological explanation of organic succession did not prove equally fruitful.49

Although the rejection of teleological explanation made possible a new range of theories of the development of life, it brought with it new problems as well. As long as it was scientifically respectable, the teleological explana-
tion of succession was attractive to a large class of naturalists because of its antievolutionary implications. While the teleological explanation did not make all naturalistic theories of the introduction of new organic forms impossible, it did rule out theories of descent. In insisting that organic structure is completely accounted for by the "principle of adaptation," the teleological explanation excluded all other possible determinants of structure, such as heredity. For many of the generation of biologists whose scientific careers began around 1830, it appeared that the results of investigations in comparative anatomy, paleontology, embryology, and geographical distribution during the first half of the century had made the teleological explanation of organic succession untenable. In their day-to-day work, geologists like Lyell and Sedgwick did not have to deal with the new biological knowledge on a serious intellectual level, which helps explain, perhaps, why they generally held fast to the teleological point of view right through the 1850s. Biologists, however, who did have to, were forced to adopt a new scientific stance. For those who were willing to entertain the idea of descent, the problem confronting them was principally one of redefining for themselves and those of their colleagues who remained teleologists the relationship of the new biological doctrines to natural theology. Others, who were not willing to consider descent theories, faced the additional problem of finding new scientific grounds for their convictions.

Agassiz, who falls into the second category, argued that it was necessary to put natural theology on a new basis. He wished to rid it of the unsophisticated "proofs" of the existence of God which characterized the Bridgewater treatises and to find it instead on the most recent improvements in biological science. The adaptation of means to ends, he said, is not only an inadequate explanation of organic structure but also an inadequate proof of the existence of an intelligent creator. "For we can conceive," he said, "that the natural action of objects upon each other should result in a final fitness of the universe, and thus produce an harmonious whole." What it is not possible to conceive, Agassiz argued, is that mere matter in motion could produce the vast intellectual scheme whose existence biological investigation is daily uncovering. Biologists contribute most effectively to natural theology not by discovering more examples of the adaptation of structure to function and organism to environment, but rather by discovering the laws which constitute the Creator's plan. In defense of his antievolutionary position, Agassiz insisted that these laws themselves prove that organized beings owe their successive appearance on the earth to the "immediate intervention of the Creator." The Creator's intervention, however, was not, in Agassiz's opinion, miraculous: "the very nature of these [organized] beings and their relations to one another and to the world in which they live exhibit thought, and can therefore be referred only to the immediate action of a thinking being,
even though the manner in which they were called into existence remains for the present a mystery."

On the question of whether creation was due to divine intervention or to the continuous operation of natural causes, Owen and Carpenter disagreed with Agassiz. Owen thought that, rather than divine intervention, the facts of morphology and paleontology suggested that the introduction of new species was due to "natural laws or secondary causes." And Carpenter supposed that the laws which define the plan of creation were subordinate to one "simple law," impressed on matter in the beginning, which brought about the creation of the universe and the creation and succession of life, all in accordance with a divine plan. In their discussions of natural theology, however, Owen and Carpenter were quite close to Agassiz.

Carpenter, like Agassiz, urged that the natural theologians relied on a weak argument for the existence of God. Adaptation, he said, might be the result of natural selection rather than design:

However absurd the assertion may seem to those who have not considered the question as a matter of strict reasoning, it would be difficult to prove a Designing Creator, only from individual cases of adaptation of means to ends. If all extraneous evidence that each race had a beginning (such as that afforded by Geology, as well as that of Revelation), were annihilated, no proof could be adduced that they have not been eternally reproducing themselves as at present. And, if any number of living beings had come into existence, without that adaptation to their conditions of existence which we observe in those now living, they would long ago have disappeared from the surface of the globe. In fact, it has been from changes in the external conditions to which they had not the power of conforming, that many races have become extinct. It might be argued, then, that the cases in which we observe this adaptation are only those in which it chanced to exist, out of a much larger number in which it was deficient; and, however improbable such a supposition may be, it would not be easy to prove its impossibility.

The best proof of creative intelligence, Carpenter thought, lay in the "comprehensive plan" of creation, which could only be the product of "Infinite Wisdom." Only by rejecting the teleological method, he said, is the naturalist able to discover the Creator's plan.

Owen in his efforts to nullify the natural theologians laid stress on the benefits which result from knowledge of morphological principles. It is true, he conceded, that the rejection of final causes in favor of such laws as conformity to a general pattern or type implies that in one sense some organic structures are "made in vain"—that is, not made for a particular, identifiable purpose—a repugnant proposition, from the point of view of natural theology, and one which, according to Whewell and Kant, contradicts the fundamental postulate of biological science. But it is the study of precisely those organs and structural patterns which cannot be explained by their functions that leads
the discovery of important truths about the organic world. Such structures are not made in vain, Owen said, if their "true comprehension lead rational and responsible beings to a better conception of their own origin and Creator." Owen's reference to man's origin suggested that vestigial organs, for instance, might be of value, from a natural theological perspective, because they provide insight into the way in which man has been derived from the "lower" vertebrates. It is not surprising that Sedgwick found his friend Owen's opinions disturbing. Owen himself, however, thought that he was performing a valuable service not only to science but to theology. He thought that his scientific work refuted atheism. The Greek atomists, he said, argued that if the world was made by a deity, then the idea of the world must have existed before the world itself, a notion which they dismissed. Owen believed that his discovery of the ideal type or pattern of the vertebrates, the archetype, proved that ideas indeed existed before things: "the recognition of an ideal Exemplar for the Vertebrated animals proves that the knowledge of such a being as Man must have existed before Man appeared. For the Divine mind which planned the Archetype also foreknew all its modifications." Owen, Carpenter, and Agassiz were all saying very much the same thing, and it is not difficult to find other examples of biologists who adopted a similar point of view at about the same time. One such, who has previously attracted the notice of historians, is Theodor Schwann. In almost the same terms that Carpenter employed, Schwann argued that there is as little room for teleological explanation in biology as there is in the physical sciences. Teleological explanations in biology, Schwann urged, are of no more value than it would be to say that the motion of the earth around the sun is an effort of the fundamental power of the planetary system to produce a change of seasons on the planets, or to say, that ebb and flood of the tides are the reaction of the organism of the earth upon the moon.

In physics, all those explanations which were suggested by a teleological view of nature, as "horror vacui," and the like, have long been discarded. But in animated nature, adaptation—individual adaptation—to a purpose is so prominently marked, that it is difficult to reject all teleological explanations. Meanwhile it must be remembered that those explanations, which explain at once all and nothing, can be but the last resources, when no other view can possibly be adopted; and there is no such necessity for admitting the teleological view in the case of organized bodies.

Like Carpenter in his review of the History of the Inductive Sciences, Schwann rejected the idea of Kant and Whewell that biology must employ a method—teleology—which is essentially different from that of the physical sciences. He believed, nonetheless, that organized beings, and the inorganic world as well, show adaptation to purpose. "We know, for instance, the powers which operate in our planetary system," he said. "They operate, like all physical powers, in accordance with blind laws of necessity, and yet is the planetary system remarkable for its adaptation to a purpose. The ground of this adaptation does not lie in the powers, but in Him, who has so constituted matter with its powers, that in blindly obeying its laws it produces a whole suited to fulfill an intended purpose." The organic world too, with all its adaptations, may well be the result of laws established by God in the beginning.

Naturalists in the mid-nineteenth century generally remained committed to the belief that the universe exhibits both order and purpose, however inadequate or philosophically unsatisfying teleological explanations of its component parts might be. This was as true of Schwann as it was of Agassiz, Owen, or Carpenter. To professional biologists such as these, it was becoming increasingly clear that the facts of their science were incompatible with a strictly teleological interpretation of nature. But at the same time they wished to affirm their continuing belief in a "wider teleology," to use Huxley's expression. After 1859, as many biologists began to advocate a directed or purposive evolution, this attitude became very popular. It is generally supposed that theories of purposive evolution represent the post-Darwin retreat of traditional natural theology. In some instances, perhaps they do. But the position had already been staked out in the two or three decades prior to the publication of the Origin of Species.

VI

The shift away from teleological explanation, which I have described, provides us with a new avenue of approach to the biological debates of the mid-nineteenth century. In the past the terms in which the natural history of this period has been discussed have usually been those supplied by the facile pen of Thomas Henry Huxley. Immediately after the Origin of Species appeared, Huxley suggested that naturalists could be divided into two main camps, evolutionists and creationists, the latter group rather large in number, the former quite small. Huxley's scheme of classification has been enormously influential. But except for informing us that there were few evolutionists in 1859, it is not very useful. It jumps into a single category—and therefore tells us little about—the vast majority of naturalists who in the 1850s were not evolutionists. There are two major defects in Huxley's scheme which merit particular notice. In defining "creation" as the introduction of new species by a "supernatural creative act," he ignored contemporary usage and attributed to the majority of naturalists an opinion which few in fact held. From the 1820s and 1830s on, a growing number of biologists and geologists, without necessarily adopting the idea of evolution, rejected super-
natural causation, and the word “creation” ceased to imply divine intervention in the ordinary course of nature.\footnote{66}

If we correct Huxley’s definition of “creation,” a second, more serious difficulty, remains. The greatest problem with the division into evolutionists and creationists is that it takes as its principle of classification an issue—the cause of the introduction of new species—on which many were uncommitted before 1859. The confusion which has resulted was only to be expected. Naturalists who had fundamentally different ideas about the development of life and the nature of biological explanation have been grouped together merely because neither accepted the idea of evolution—Sedgwick and Agassiz are an example. And others who agreed on a number of important issues have been separated if one committed himself to the idea of evolution, while the other maintained a neutral stance—for instance, Owen and Robert Chambers or Baden Powell. An equally serious distortion results from the tendency of the evolutionist-creationist distinction to be subtly transmuted into the distinction between friends and foes of Darwin. Then Owen and Carpenter, whose ideas on organic succession seem to have been virtually identical both before and after 1859, are placed in separate camps because Owen was hostile to Darwinism while Carpenter was receptive. And Carpenter and Lyell, who agreed on very little until Lyell’s acceptance of evolution in the 1860s, are placed together among the “progressives.”\footnote{67}

I believe that we gain a more adequate conception of the history of biology in the period before 1839 and of the impact of the Origin of Species if we replace Huxley’s categories with others which reflect more closely the divisions among naturalists in the mid-nineteenth century. Of the many issues over which biologists disagreed around 1830, the most fundamental, I think, was the issue of biological explanation. It was their position on this issue which dictated what sorts of theories they held about the organic world. Instead, then, of grouping naturalists as evolutionists and creationists, I would separate those who advocated teleological explanations from those who sought to explain organic structure and succession by biological laws and forces. Lyell, Sedgwick, Buckland, de la Beche, Charles Bell, and many more fall into the first division; Owen, Carpenter, Agassiz, Chambers, Powell, Wallace, Darwin, Spencer, and others into the second. Those in the first group accepted no explanation for the successive appearance of different types of organism except the principle of adaptation to changing conditions. They consequently held that there is a strict parallel between the history of the earth and the history of life. Those in the second group believed that the forms of the animals which succeed one another depend on more than adaptation to conditions, for they recognized that there are structural similarities between them which cannot be directly explained in functional terms. Some members of the second group maintained the general idea of a parallel by making the development of the earth the motive force behind the evolutionary development of life. Chambers, for instance, proposed such a theory in the early editions of the Vestiges of the Natural History of Creation.\footnote{68} However, the majority of those in the second division, while attributing varying degrees of influence to changes in the environment, described the development of life as the result of biological laws, rather than the directional development of the earth.

Although I consider the division into teleologists and nonteleologists to be of primary importance, further distinctions may, of course, be traced among members of each of these two principal groups. Among the teleologists there were some, such as Lyell, who were careful not to commit themselves to the opinion that the Creator was directly involved in the production of new species; while others, such as Sedgwick, referred the introduction of species to acts of “creative interference.” Among those who abandoned teleological explanation, Agassiz doubted that the creation of species could be explained by continuously acting natural causes. On the other hand, Chambers, Spencer, Powell, Darwin, and Wallace were evolutionists. There existed as well a middle ground between these extremes. Owen and Carpenter, though committed to the idea of creation by continuously acting natural causes, before 1859 had not publicly expressed views which could be called evolutionary. Their intermediate position was undoubtedly shared by others.\footnote{69}

Probably every historian who studies this period will be able to think of at least one issue which might serve as the basis for refinements or even major revisions in the scheme I have outlined. For instance, the evolutionists, to carry the process of subdivision yet a step further, may be divided into those, such as Chambers and Powell, who believed in a preconceived plan of organic development and those, such as Darwin, who did not. Or it might be argued, as Camille Lenèges does, that Darwin, by abandoning entirely the idea of perfect adaptation, set himself apart not only from the teleologists but also from those who rejected teleological explanation but remained convinced of the harmony and purposiveness of the whole creation.\footnote{70}

I am far from believing that my classification is perfect. But I cannot help thinking that it is very much better, as a description of the state of mid-nineteenth-century natural history, than the evolutionist-creationist dichotomy. Huxley’s scheme was no doubt a useful polemical device during the debates over the Origin of Species. But it gives us little help toward an understanding of the history of biology in the crucial middle decades of the nineteenth century. The division into teleologists and nonteleologists, I think, does give us such help. It effectively distinguishes between those biologists whose laws of organic succession were a major contribution to post-1850 biological theory and the geologists and older biologists whose teleological progression and nonprogression theories were obsolete at least a decade be-
fore the publication of the *Origin of Species*. Put more simply, it tells us that Charles Bell's work on *The Hand* and other similar Cuvierian and natural theological treatises are not to be taken as typical representatives of pre-Darwinian opinion on the questions of organic structure and succession, for in the thirty years before 1859 there occurred a fundamental shift in the nature of biological explanation.

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NOTES


2. See, for instance, Henry Brougham and Charles Bell's edition of William Paley's *Natural Theology*, 2 vols. (New York: Harper and Brothers, 1839 [London, 1830]). Brougham and Bell emphasized more strongly than Paley the perfection of adaptations. Paley himself said that adaptations are not perfect in an absolute sense ("comparative, by its very definition and nature, is the refuge of imperfectness"), but they are as perfect as is possible within the limits imposed by the general laws of matter and by God's desire to make manifest to man the existence, agency, and wisdom of a creative intelligence (1: 112-14; Paley, *Natural Theology* [3rd ed.: London, 1803], pp. 41-43).

3. For brief discussions of Cuvier's views on explanation, see Coleman, *Cuvier*, pp. 38-43; and E. S. Russell, *Form and Function* (London: John Murray, 1916), pp. 31-44, 76.


11. Ibid., pp. 362-64.

12. MS. 42, d4, Owen MSS, Royal College of Surgeons.
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34. The progressionist geologists would almost certainly have defended themselves against any imputation of determinism by referring to their frequent insistence that the perfect fit between organisms and environment was due as much to adaptation of the environment to the organisms as to the reverse. Lyell too believed that the organic and inorganic worlds were parts of a single plan of creation, but he recognized that in treating change in the inorganic world as primary (which the progressionists did as well), he was creating a deterministic theory of change in the organic sphere.


38. Ibid., pp. 21–22.

39. Ibid., pp. 17, 141–52; also, Agassiz's summary of Chapter 1, pp. 193–206.


46. J. P. Pitou's statement that "from Cuvier to Darwin, paleontology made little progress, though some good descriptive work was done," accurately describes the contributions of the Cuvierian paleontologists. It ignores, however, the important work of those who rejected the teleological method. Pitou, "Vertebrate paleontology," in *History of Science in the Nineteenth Century*, René Taton, ed. (New York: Basic Books, 1969), p. 447.


48. We saw above, for instance, that Lyell had no difficulty in ignoring that part of De Candolle's work which did not suit his purposes.


50. Ibid., pp. 17, 205.


54. Ibid.

55. Ibid., section II.


61. Ibid., p. 187.

62. Thomas Henry Huxley, "On the reception of the 'Origin of Species,'" in *Life and Letters of Charles Darwin*, Francis Darwin, ed., 2 vols. (New York: D. Appleton and Co., 1888), I: 554. Thomas McEvans, in *The Argument from Design* (New York: Macmillan, 1972), distinguishes between two forms of the design argument, design in the sense of purpose and design in the sense of order. The former is the design of the teleologists, the latter is the "wider teleology" of the mid-nineteenth-century biologists. Two recent books have drawn attention to this distinction in discussing the natural history period of the later period between Cuvier and Darwin: Mary P. Wimsatt, *Stanford, Jellis, and the Order of Life: Issues in Nineteenth Century Science* (New Haven: Yale University Press, 1976), pp. 139–41, 177–78; and Bowler, *Fossils and Progress*. Bowler, however, distinguishes the progressionism of Agassiz or Owen from that of Sedgwick or Backlund less by its rejection of teleological explanation than by the idea that man is the goal of the order of life. In *Lyell's View*, I think he is mistaken, for Owen's and Carpenter's views cannot be described in this way.


Louis Pasteur and Molecular Dissymmetry, 1844–1857

Dorian B. Kottler

I. Introduction

Louis Pasteur devoted his scientific career primarily to studies in the life sciences. From his earliest work on fermentation in 1855 to his development three decades later of vaccines against such diseases as rabies and cholera, Pasteur was involved almost entirely with questions of a biological or medical nature. It is chiefly for his contributions to pathology that the world remembers him today. Yet Pasteur did not begin his life’s work as a specialist in these areas. For more than a decade, starting in 1844 in his first year as a student at the École Normale in Paris, Pasteur’s scientific interests were in the fields of crystallography and chemistry. Only with his experiments on fermentation did he begin to turn his research efforts specifically to biological subjects.

A full historical analysis of Pasteur’s thought must therefore deal with the question of the nature of the transition he made from the study of nonliving to that of living phenomena. That transition can be followed in the development in his approach to the problem of molecular dissymmetry. The physicist Jean-Baptiste Biot early in the nineteenth century had postulated a dissymmetric, or twisted, configuration of the atoms constituting the molecules of certain substances in order to explain their optical activity, or ability to rotate the plane of polarized light passed through them. Pasteur first became interested in molecular dissymmetry because of its apparent relationship to crystal structure. He was occupied for several years with experiments designed to study this relationship.

Beginning in 1855, however, at the time of his earliest work on fermentation, Pasteur emphasized quite another aspect of molecular dissymmetry. He