Without Miracles

15 From Providence Through Instruction to Selection: A Well-Traveled Road

---

Looking back into the history of biology, it appears that wherever a phenomenon resembles learning, an instructive theory was first proposed to account for the underlying mechanisms. In every case, this was later replaced by a selective theory. Thus the species were thought to have developed by learning or by adaptation of individuals to the environment, until Darwin showed this to have been a selective process. Resistance of bacteria to antibacterial agents was thought to be acquired by adaptation, until Luria and Delbrück showed the mechanism to be a selective one. Adaptive enzymes were shown by Monod and his school to be inducible enzymes arising through the selection of preexisting genes. Finally, antibody formation that was thought to be based on instruction by the antigen is now found to result from the selection of already existing patterns. It thus remains to be asked if learning by the central nervous system might not also be a selective process; i.e., perhaps learning is not learning either.

--Niels Jerne[1]

It is nevertheless worth noting that in the history of ideas "instructive" hypotheses have most often preceded selective hypotheses. When JeanBaptiste Lamarck tried to found his theory of "descendence" on a plausible biological mechanism, he proposed the "heredity of acquired characteristics," a tenet that advances in genetics would eventually destroy. One had to wait almost half a century before the idea of selection was proposed by Charles Darwin and Alfred Wallace and validated the principle, if not all the details of its application. In the same way the first theories about the production of antibodies were originally based on instructive models before selective mechanisms replaced them. It could conceivably be the same for theories of learning. To understand the reasons for this temporal succession, we must obviously examine the functioning of the scientist's brain. An instructive concept consists of only one step. It is the simplest possible approach. Moreover, whether we like it or not, it contains an "egocentric" component. "Nature directs forms" much as the sculptor models clay into a statue. . . . The concept of selection, on the other hand, implies further reflection. It involves two steps, and it satisfies the quest for a material mechanism totally devoid of "intentional" aspects. It is natural that this more complicated procedure, more difficult to execute, should have systematically appeared in second place throughout the history of scientific thought.

--Jean-Pierre Changeux[2]

. . . chance alone *is at the source of every innovation, of all creation in the biosphere. Pure chance,*

absolutely free but blind, at the very root of the stupendous edifice of evolution: this central concept of modern biology is no longer one among other possible or even conceivable hypotheses. It is today the sole *conceivable hypothesis, the only one that squares with observed and tested fact. . . . There is no scientific concept, in any of the sciences, more destructive of anthropocentrism than this one, and no other so arouses an instinctive protest from the intensely teleonomic creatures that we are.*

--Jacques Monod[3]

Having now surveyed so many different fields of knowledge, it is finally time to entertain some general conclusions concerning their origins, insofar as such forms of knowledge are considered to be characterized by adapted complexity and constitute puzzles of fit of one system to another. Certainly, one conclusion should already be quite obvious, as it has provided the basic theme of this book--that selectionist theories have now been advanced in all these domains to account for the origin and growth of adapted complexity. But another similarity across many of these fields is also quite striking--remarkably similar patterns of evolution are evident in the growth of human knowledge itself.

Changing Perspectives on Fit

Biology provides one of the clearest examples of this progression of understanding. As we saw in chapter 2, the first reasoned explanation for the adapted complexity of living organisms was an extension of our everyday understanding of how the world works. As Reverend Paley so eloquently reasoned in *Natural Theology*, if we find a watch we naturally assume that the watch must have had a maker and the intricate design and function of the watch are due to the intelligence and skill of its creator. Similarly, Paley reasoned, an examination of the complexity in the functional design of living organisms leads to the conclusion that these life forms also had a creator, and that the adapted design and intelligence of these organisms is a reflection of the creator's knowledge, skill, and power. From this perspective, organisms, like watches, are considered to be the products and passive recipients of the knowledge provided by a supernatural entity in this providential theory of adapted complexity. Although modern biological science in its quest for naturalistic explanations no longer considers this to be a viable theory, it is probably still the most popularly held belief concerning the origin of the biosphere among nonscientists, even in a technologically advanced country such as the United States.

But it eventually became clear to some that living organisms were not the finished, final product of an omniscient and omnipotent creator. Instead, the accumulating fossil evidence indicated that the biosphere has undergone--and is still undergoing--dramatic changes, with some species dying out, new ones appearing, and others undergoing extensive modifications. Lamarck's explanation for these changes did not explicitly reject God's graces, but added another mechanism by which organisms would be modified advantageously by their interactions with the environment in ways that were passed down directly to their descendants.

Lamarck's theory of evolution had some important advantages over Paley's purely providential account of the design of life forms. It took into account the fact that species are not immutable but rather change over time. It also attempted to provide a naturalistic theory of evolution that did not rely exclusively on the omniscience and omnipotence of a supernatural being. But Lamarck's instructionist theory was inadequate to the task of explaining biological evolution, as it provided no explanation for either why the modifications undergone by organisms in their interaction with the environment should be adaptive (why should exercise make a muscle stronger or cold weather make a mammal's fur grow thicker?), or how these modifications could be transmitted to the next generation. The theory was an important step in moving from a supernatural to a naturalistic understanding of adaptive evolutionary change, but it did not go far enough in that it still required processes that were "smart," and the origin of this smartness was itself unaccounted for.

Natural selection provided an alternative explanation that removed all smartness from the process. Organisms varied, but why, Darwin did not pretend to know. By absolutely blind and ignorant luck, certain variations were better adapted to their environment, giving them a competitive edge over other organisms and allowing them to leave behind more offspring. These offspring, being more like their parents than not (again, Darwin did not know why), would share the traits and reproductive success of their parents, but with continued variations in their own offspring.

Darwin's account required no divine providence. Neither did it have magical instructions from the environment telling organisms how to adapt and how to pass on this information to their progeny. Darwin hit on a theory that, although incomplete because of his understandable ignorance of genetics and molecular biology, provided the first explanation for how adapted complexity could emerge on its own with no outside guiding hand or mysterious environmental instructions. But despite his insight that so stunned the world of science, he was unwilling to reject completely either the providentialism of Paley or the instructionism of Lamarck. As he stated in the first edition of the *Origin* and repeatedly emphasized in later editions, "I am convinced that natural selection has been the main but not the exclusive means of modification."[4] We will see later that he also did not reject a providential account of life's initial emergence.

And so it was left to the younger and more radical ultraselectionists, in particular August Weismann, to assert toward the end of the nineteenth century that natural selection was the sole process by which species grew in adapted complexity. And now more than 100 years later, this purely selectionist view of the emergence of design has so far withstood all challenges (including some quite recent ones to be considered in the next chapter) and continues to be the foundation for modern biology.

As recounted in chapter 4, a remarkably similar sequence of theory evolution, from providential through instructionist to selectionist, can be seen in the field of immunology. Ehrlich's original side-chain theory of antibody production was providential not in the sense of calling on God as an active creator of antibodies, but rather because it assumed that the information necessary to produce all possible antibodies was already contained in the genome.[5] But this theory was cast into doubt when it was realized that the immune system could produce antigens that were able to match and thereby recognize as foreign completely novel microscopic invaders.

As in biology, the first nonprovidential theory proposed for the functional design of antibodies was an instructionist one with a definite Lamarckian flavor. The template theory proposed that antibodies obtained information for their production from their environment, that is, from the antigens with which they came in contact. But after about 20 years it became apparent that the template theory could not account for certain key findings, such as that later-produced antigens were usually more effective in binding with an antigen than earlier ones.

To explain these findings, Jerne proposed a selectionist theory of antibody production that in its basic conceptualization is still accepted today. The building plans for antibodies are not all specified in the genome. Nor are antibodies created from instructions or templates obligingly provided by the invading antigens. Instead, new antibodies having remarkable fit to a given antigen are produced through the random generation of a large population of varied antibodies, with those having the best fit selected for additional rounds of blind variation and selection.

So as in evolutionary biology, immunology proceeded through the same stages to explain its puzzle of fit. The formulation and acceptance of a selectionist theory of antibody production was of particular significance since it provided the first clear demonstration that the same basic process of cumulative blind variation and selection that occurs over eons of phylogenetic time among organisms also occurs within organisms during their much shorter life spans.

Although selectionist theories of the achievement of fit have become mainstays of evolutionary biology and immunology, they have not been well accepted into other fields seeking explanations for the puzzles of fit in animal and human learning, human thought, scientific progress, and cultural adaptation. In philosophy, the selectionist perspective is well represented by the work of Popper. But Popper's emphasis on human fallibilism and his evolutionary epistemology (which sees all knowledge growth as never-ending cycles of conjectures and refutations) is not very popular today. A minority of philosophers see his work as an important advance, but mainstream philosophy seems more attached to providential and instructionist theories of the origins of knowledge. An example of current providentialism is the linguistically influenced innatism of Chomsky and Fodor, and instructionism survives in the continuing efforts to wrestle with the problem of induction in attempts to explain how our limited sensory experiences can instruct us with justified, certainly true beliefs about the world.

Much the same state of affairs can be seen in the cognitive and social sciences. Despite the work of Campbell and a handful of others, the view that perception and cognition constitute forms of substitute trial-and-error-elimination is not widely held among psychologists and cognitive scientists. The same appears generally true of sociology, anthropology, and other fields concerned with understanding the dynamics of human culture and social institutions. So selectionist accounts of cognition and culture certainly exist, but mainstream currents in these fields still seem to vacillate between the providentialism of innatist theories (as in E. O. Wilson's sociobiology[6]) and the instructionism of much learning theory, which sees the environment in control of behavior.

Selection theory is doing somewhat better in the neurosciences, partly due to the influence of Changeux[7] and to Edelman's neural Darwinism. But there continues to be much resistance to selectionist theories of brain development and functioning, perhaps at least partly attributable to the difficulty of Edelman's writing[8] and possibly resentment against an outsider from the field of immunology attracting so much attention in the neurosciences.[9]

The largest successes of selection theory outside biology, immunology, and agriculture have been in the design of computer programs and molecules. But even here, particularly in computer science, much resistance remains. For many, resorting to the creative powers of ignorant, cumulative variation and selection as implemented in genetic algorithms and programming is an admission of programming incompetence, forcing one to rely on the computation muscle of fast, parallel processors to find a brute-force solution in the form of a hacked program that may do the job, but is inelegant and perhaps even incomprehensible to the programmer's eye.

The Rejection of Selection

Why are selectionist theories of design so little known and used in the scientific community outside of evolutionary biology and immunology to explain puzzles of fit and the growth of knowledge? There appear to be a number of reasons, some of which were mentioned in the discussion of biological evolution in chapter 2. But nowhere has more debate arisen than in the attempt to apply it to the growth of human knowledge in fields such as the philosophy and history of science, psychology, and cultural change. And so it is back to these fields we will turn to consider the arguments against a selectionist account of the ontogenetic growth of knowledge.

The Wastefulness and Improbability of Selection

Some of the arguments against a within-organism selectionist account of human knowledge growth are much the same as arguments that were (and still are) put forward against natural selection as an account of the adapted products of organic evolution. Some of them are primarily based on religious or aesthetic considerations. We saw in chapter 9 that Piaget rejected both Darwin's selectionist account of evolution and any application of selection theory to the cognitive domain, citing the "alarming waste" and the "fruitless trials" accepting such a theory would entail. Indeed, Piaget's concerns were warranted, even if his conclusions were not. The process of cumulative blind variation and selection is exceedingly wasteful since almost all variations, ignorant as blind probings must be, are dead ends (literally so in organic evolution). But this wastefulness can be understood as the unavoidable price that must be paid for a process from which new adaptations and knowledge can emerge without miraculous outside providentialist insights or mysterious instructionist guidance.

That we tend to forget or ignore the many failures in our attempts to better understand and control our surroundings and remember only the successes makes a selection theory epistemology appear unnecessary and unappealing. This is much the same as considering only the living and adapted end results of biological evolution and ignoring the countless unadaptive variations. But unlike biological evolution where the failed organisms and extinct species are usually well hidden from view, we can take notice of the fruitless trials of our experiments and conjectures.

An informative case from the history of technological innovation is Thomas Alva Edison's two-year attempt to find an appropriate substance for the filament in the first electric light bulb. After trying out dozens of substances, including red hair from a man's beard, Edison finally found success in December 1879 using carbonized sewing thread. His oft-quoted statement that "genius is 1% inspiration and 99% perspiration" reflects the long hours and countless failures that accompanied this and his many other inventions and technological advances.

But when we buy a new product, whether it be a new video camera or a more effective laundry detergent, we take no notice of the many failed attempts that preceded its development. We also know nothing of the countless would-be inventors and scientists who do not produce noteworthy breakthroughs. We usually consider only the successes and not the failures, making it appear as if science and technology progress through the sheer brilliance and insight of scientists and inventors rather than through painstaking trial and error and only occasional exhilaration of trial and success. Walter Vincenti, whose account of advances in aeronautical engineering was introduced in chapter 10, remarks:

> From outside or in retrospect, the entire process tends to seem more ordered and intentional--less blind--than it usually is. It is difficult to learn what goes on in even the conscious minds of others, and we all prefer to remember our rational achievements and forget the fumblings and ideas that didn't work out.[10]

Another argument against selection theory stresses the improbability of a blind, unintelligent process coming up with useful solutions to complex problems. This same argument was used repeatedly against natural selection in the evolution of species. It is of course true that any single blind change to a working system is almost certainly not going to make that system function better. A random wiring change inside the computer I am using to record these words is quite unlikely to make it perform better and much more likely to lead to a trip to the repair shop. However, iterative cycles of blind variation and selection based on large populations of such variations is quite another matter. The recent impressive successes of selectionist approaches to the design of both computer programs and molecules may convince some of the more open-minded skeptics of selection theory that such a process working cumulatively on populations can effectively tame the improbability of a blind process generating a fitter solution.

Examining Variation, Selection, and Transmission

But not all who argue against selectionist accounts of the growth of knowledge are offended by the wastefulness of variation and selection, nor do they all doubt its power, at least not in biological evolution. Rather, some insist that there are important differences between the biological evolution of adapted complexity and the growth of knowledge as manifested in both the progress of science and the cognitive development of the individual human brain. These arguments focus on the three principal themes of variation, selection, and transmission.

Probably the most frequently raised objection against the selectionist view of knowledge growth takes the form of an argument against the view that the variations are generated *blindly* as to their ultimate success. Other equally unflattering adjectives such as "unjustified," "unforesighted," "nonprescient," "undirected," "haphazard," "random," "groping," "stupid," and "dumb" have also been used to describe these necessary variations, but the word *blind* perhaps makes the essential point most clearly.

The argument against blindness in the variations of thought and theory leading to advances in human knowledge is that, although in biological evolution the generation of genetic variations may indeed be blind, the growth of human knowledge is consciously and purposely directed toward finding solutions to specific problems. As University of Waterloo (Canada) philosopher of science and cognitive scientist Paul Thagard proposed:

> Whereas genetic variation in organisms is not induced by the environmental conditions in which the individual is struggling to survive, scientific innovations are designed by their creators to solve recognized problems; they therefore are correlated with solutions to problems . . . Scientists also commonly seek new hypotheses that will correct error in their previous trials . . .[11]

But, we must ask, how does the fact that scientists have purposes (which few would doubt) provide emancipation from the necessity of blind variations in pushing back the frontiers of knowledge? The fact that a young scientist may be spending almost all of her waking hours in pursuit of room-temperature superconductivity does not, unfortunately, provide her with any clairvoyance as to the desired solution, if one does exist. Stating that these variations are "correlated with solutions to problems" begs the question as to how such prior guiding knowledge might have been achieved in the first place. Our scientist, unlike the process of organic evolution, most certainly does have a definite goal, and she generates methodological and theoretical variations in an attempt to accomplish this goal. But to the extent that new discoveries are made for which prior knowledge did not exist, this growth of scientific or technological knowledge is possible only by producing and testing new experimental variations *whose outcomes are unknown until tested*.[12] As Campbell put it, "rather than foresighted variation, hindsighted selection is the secret of rational innovation."[13]

But we must be careful to make clear what is meant by *blind* in this context. First, blindness does not imply that all variations are equally probable. For this reason, the word *random* is probably not a suitable descriptor since to some it may carry that connotation. Second, blindness does not mean that the process of producing variations of ideas, theories, and experiments for testing is necessarily unconstrained. Our superconductivity-seeking scientist is not likely to throw just anything into her concoction of chemicals, such as some of last night's leftover soup. Instead, she will rationally try out those substances in those proportions and under those conditions that, based on her knowledge of previous research and current theory, she believes have the greatest chance of success.

So it cannot be denied that previously achieved knowledge has an important role to play in constraining the variations to be investigated. Nonetheless, the new concoction is still a blind variation in the sense that the scientist does not know, and cannot know, if the resulting material will be an improvement over previous ones. It is in this important sense that the variation, although far from random and unconstrained, remains blind. The manner in which you grope about in a dark room to find the light switch changes significantly after making contact with the wall on which the switch is located. What were three-dimensional gropings now become two-dimensional ones. And as you encounter the molding along which you know the switch is located, your gropings become further constrained to just one dimension. But although they may become progressively and usefully constrained over time, an unavoidable blind component exists in your gropings until you actually find the switch. The same could be argued--although it is a much harder sell--about our use of vision to find objects and help us navigate around our environment (recall the discussion of the blind man in chapter 9).

To the extent, however, that constraints are effective in advancing knowledge (for example, whatever it is that prevents the scientist from adding the soup to her would-be superconducting material), they must be seen as additional puzzles of fit requiring explanation. And unless we are to return to providential or instructionist explanations for the existence of these adapted constraints, they can be explained only as the products of prior blind variation and selection.[14] As such, they may be quite well suited to guiding research into new, unexplored areas. But their fallibility must also be recognized since their use in finding answers to new problems may on occasion actually hinder progress rather than facilitate it. So, "it is not only the case that there is no prescience about which variations will lead to success, there is also no prescience about what part of the wisdom already achieved must be abandoned in order to go beyond it. In exploring new regions the cognitive constraint system is itself up for grabs."[15]

It has also been argued that the process of selection in the advancement of human knowledge is very different from natural selection in biological evolution. Again, Thagard contrasts humans as intentional agents in their role as selectors of theories in the growth of scientific knowledge with purposeless natural selection:

> The differences between epistemological and biological selection arise from the fact that theory selection is performed by intentional agents working with a set of criteria, whereas natural selection is the result of different survival rates of the organism bearing adaptive genes.[16]

This certainly is a noteworthy difference, but we must again ask how it in any way invalidates a selectionist explanation of scientific achievement. In biological evolution, organisms that by the luck of their genome are better suited to their environment leave behind more progeny and therefore more copies of their genes than those less well adapted. It is this winnowing away of the less-fit organisms, not any foresightedness or clairvoyance on the part of the genetic variations, that is responsible for the fit of organism to environment. And different environments result in the selection of different adaptations, such as wings and lungs for air, and fins and gills for water.

Similarly, science progresses by the selection of theories that better fit the criteria used by scientists, such as explanatory power and parsimony. This is not to deny that certain practices and criteria used by scientists and communities of scientists may be irrelevant or even detrimental to the progress of science, such as the tendency to fund or follow a line a research due solely to the power, prestige, or popularity of its leading proponent. But insofar as science becomes progressively better at describing and explaining the objects, forces, and processes in the universe, it must be because the universe somehow interacts with the experiments and thoughts of scientists and thereby plays a role in determining which theories and hunches will be retained.

It has also been noted that biological evolution shows divergence leading to a great diversity of life forms, whereas science in marked contrast ultimately leads to convergence. The biosphere is rich in many strikingly different types of life forms, but physicists the world over use the same theories of relativity and quantum physics to account for and predict mechanical events. This difference has been taken by some as evidence that organic evolution and conceptual development must be fundamentally different. Thagard points out this difference by stating that

> survival of theories is the result of satisfaction of global criteria, criteria that apply over the whole range of science. But survival of genes is the result of satisfaction of local criteria, generated by a particular environment. Scientific communities are unlike natural environments in their ability to apply general standards.[17]

But just how are scientific communities able to apply these "general standards"? Is it not because the local criteria of modern scientists are much the same no matter where on the globe they may be located? The most obvious explanation for why scientific theories tend to converge is that they all share a very similar local environment. Light behaves very much the same in Sri Lanka as it does in Switzerland. So do falling bodies, chemical reactions, and cell division. Indeed, much of the technology and effort of scientific research is directed toward ensuring that experiments are conducted under highly controlled conditions that can be duplicated elsewhere with the same results. Thus a successful experiment that reveals a new regularity of nature should be replicable by other scientists with similar equipment anywhere in the world. In addition, the goals of scientists everywhere are much the same in their search for powerful yet simple theories with high explanatory and predictive powers. American biologist and philosopher David Hull addresses this issue in pointing out:

> Conceptual evolution, especially in science, is both locally and globally progressive, not because scientists are conscious agents, not because they are striving to reach both local and global goals, but because these goals do exist. Eternal and immutable regularities exist out there in nature. If scientists did not strive to formulate laws of nature, they would discover them only by happy accident, but if these eternal, immutable regularities did not exist, any belief that a scientist might have that he or she had discovered one would be illusory.[18]

So regardless of the differences between biological evolution and the work of scientists, one can argue that scientific theories, like organisms, develop as they are edited by the selection pressures of their environments, which, although necessarily local, reflect both universal (as far as we know) regularities of nature and the shared practices, beliefs, and goals of modern earth-bound researchers. The unavoidable local nature of these apparently global criteria may someday be made quite clear when life is discovered on another planet that does not conform to terrestrial theories of life, or when it is revealed that the laws of physics in the vicinity of black holes have little resemblance to those that were formulated to account for phenomena closer to home.

It should also be noted that biological evolution, like science, shows convergence when similar problems are confronted by quite different organisms. The case of flight is perhaps the most striking example, with the asymmetrically curved wing having evolved independently in insects, reptiles (the extinct pterosaurs), flying fish, birds, and mammals (bats). The similar shapes of fish and marine mammals such as dolphins and whales is another example of convergent evolution. Indeed, the phenomenon often makes it difficult for biologists to disentangle the phylogenetic relationships among organisms based on physical appearance alone. Just because two organisms share a common feature, this does not necessarily mean that they are close to each other on the phylogenetic tree. Similarly, just because two scientists may come up with the same theory to solve some problem, it does not necessarily indicate that one of the scientists took the idea from the other. The independent discovery of natural selection to explain the origin of species by both Darwin and Wallace is a case in point.

So certain aspects of selection may at first appear different in biological evolution and scientific development, but its basic function of eliminating the less fit and retaining the fitter is actually very much the same. As Campbell put it so simply, "rather than foresighted variation, hindsighted selection is the secret of rational innovation."[19] And this "hindsighted selection" is as much a feature of scientific discovery as it is of organic evolution.

Differences in the transmission of accumulated knowledge between biological (genetic) and scientific systems have also been emphasized by opponents of selection theory epistemology. It has been suggested, even by such widely recognized experts in evolutionary theory as Gould[20] and Dawkins,[21] that the cultural transmission of ideas, including scientific ones, is a type of Lamarckian instructionist process, since the knowledge discovered by one individual can be promptly passed on to another. In this sense there appears to be a type of inheritance (or at least transmission) of acquired characteristics that simply does not seem possible in biological evolution.

However, such a view of the origin and progress of scientific and cultural knowledge encounters difficulties no less severe than Lamarck's account of organic evolution. Certainly, a strict Lamarckian interpretation is untenable since "in order for sociocultural evolution to be Lamarckian in a literal sense, the ideas that we acquire by interacting with our environment must somehow become programmed into our genes and then transmitted to subsequent generations."[22]

But even if a less literal interpretation of Lamarckism were applied to human knowledge, imposing problems remain. It was stated in chapters 11 and 12 that knowledge cannot simply be transmitted from one individual to another, either by language or any other means currently known. Instead, the process of understanding the ideas of another, whether expressed in oral or written language or other signs or gestures, requires the active generation of a variety of candidate ideas on the part of the "receiver," and the subsequent selection of the best ones. Virtually all modern theories of learning, education, and knowledge acquisition emphasize the active role of the learner in the construction of meaning, even if they do not explicitly embrace a selectionist account of communication.

So although scientific and cultural knowledge may appear to be transmitted from individual to individual and from generation to generation through a Lamarckian process, this turns out to be as unlikely as the inheritance of acquired characteristics during biological evolution. For such transmission to take place, it would have to be possible somehow for the knowledge contained in my brain to be transferred to yours in the same way that I can copy the computer file containing this chapter from my disk to yours. It is possible that such a technique could be developed in the future, perhaps by reading the pattern of synapses in one brain and then rewiring part of another brain to match this pattern. Until that time, however, we must tolerate the rather slow (although still many orders of magnitude faster than biological evolution) and inefficient necessity of recreating the knowledge of others using language and educational settings as facilitators of this constructive, selectionist process.

Other Criticisms

Many other criticisms have been made of the application of selection theory to the growth of human knowledge. It would be too tedious to consider all of them here, but many if not most of them share one or more of three characteristics.

The first is taking the process of biological evolution as the gold standard of selectionism and consequently treating any differences in the mechanics of variation, selection, and reproduction between that process and the growth of human knowledge as reason enough to discount a selectionist view of the latter. But as the previous chapters should have made clear, biological evolution is just one of many instances of cumulative blind variation and selection leading to the adaptation of one system to another. So although scientific theories, cultural practices, and genes may exist in very different forms and employ distinct modes of variation, selection, and replication, these and other superficial differences have in themselves little bearing on the argument that both thought and science make progress through a process of cumulative blind variation and hindsighted selection. It is for this reason that the terms "selection theory epistemology" and "selectionist epistemology" are preferable to the original "evolutionary epistemology" proposed by Campbell in his seminal 1974 chapter. Biological evolution, insofar as it leads to increases in adapted complexity, is a selectionist process. But not all selectionist processes have to mimic adaptive organic evolution in all of its biological details.

Second, many critics fail to take into account that selection theory is necessary only to explain the emergence of *new* fit, *new* adapted complexity, *new* knowledge, and not the routine application of old knowledge. We may not require a selectionist explanation for how a scientist, having acquired the accepted knowledge of his field, is able to apply this knowledge in a rather routine fashion to his work.[23] The use of current techniques for deciphering the genetic sequences in strands of DNA as is now being done as part of the human genome project may be an example of this type of research. As one defender of Campbell's selectionist dictum (which sees all instances of increase of fit resulting from blind variation and selective retention) pointed out:

> They [critics of Campbell] have typically not been sufficiently cognizant of the fact that the Dictum concerns the origins and the advancement of knowledge and not the utilization or extension of already acquired knowledge. It is certainly not an appropriate criticism of Campbell's Dictum to note how much previous knowledge is at work in one's daily activity or show how infrequent blind search seems to occur in most of our mundane efforts. The Dictum applies only to those instances when we are going beyond what we already know.[24]

Finally, a number of critics suggest that evolution itself has endowed our species with sensory and mental abilities that make it possible for us to acquire new knowledge without resorting to wasteful blind mental variation and selection. In essence, this argument contends that selection theory is appropriately applied to the phylogenetic development of human sensory and cognitive capabilities, but it need not and should not be applied to the ontogenetic acquisition of knowledge and skills developed during the life span of individuals.[25] In the same way that a girl does not have to figure out by trial and error how to grow breasts at puberty, this having been already figured out during the course of phylogenetic development of the human species and encoded in her genes, during the course of human evolution we acquired sensory organs and brain structures that allow us to acquire new knowledge without the need for further variation and selection.

But this argument that the growth of knowledge is able to bypass variation and selection in its basic mode of operation has at least three flaws. First, the achievements of biological evolution are due to what was selected in the past, and can provide no guarantee that these achievements will continue to be of use in the future. Fortunately, many aspects of our physical environment have remained relatively stable over long periods of time so that many of evolution's achievements (such as lungs, gills, wings, and feet) are still of use today. But the fact that extinction, not perpetual survival, is the usual fate of a species attests to the tentative nature of the knowledge achieved by a selectionist process. It therefore appears unlikely that natural selection could have provided us with innate abilities for acquiring all new knowledge, particularly in fields where our usual intuitions concerning space, time, and causality are violated, as in relativity theory and quantum mechanics.

Second, as presented in chapters 4 and 5, it has become increasingly clear that at least some (and perhaps all) aspects of ontogenetic development are dependent on selectionist processes. In the mammalian immune system, it is widely accepted that the fit of antibody to antigen is not solely due to past achievements of evolution, but requires an accompanying process of blind variation and selection during the lifetime of the animal. Selectionism is not quite as firmly established in the brain sciences, but thanks to increasing evidence, there is growing agreement that the fit of the brain to the needs of its owner is largely due to a continuous process of blind variation and selection of neurons and neuronal connections. Therefore, the argument that selectionist processes underlie only phylogenetic change resulting from among-organism selection and not ontogenetic development, which is now known to require within-organism selection, is no longer tenable.

Third, some critics have pointed to instructionist procedures by which new knowledge is attained as counterexamples to the conjecture being considered here that all knowledge has its roots in cumulative blind variation and selection. One example is Pavlovian conditioning as discussed in chapter 7. It will be recalled that in Pavlovian conditioning an animal learns to make an old response to a new stimulus, as when a dog began salivating on seeing a dark-colored liquid, after having had such a liquid containing acid placed its mouth. Such learning appears instructionist, since no obvious trial and error of responses is involved, and by pairing a neutral stimulus with an unconditional one that elicits a built-in response, the environment does appear to be instructing the organism to use the neutral stimulus to anticipate the unconditional one. It cannot be denied that such learning makes an animal's behavior better adapted to its environment, as it is now able to anticipate and therefore avoid dangerous situations (such as a bear fleeing at the sight of hunters) and seek out favorable ones (as in using the squeak of a mouse to locate food).[26]

But whereas such instructionist adaptation may occur and therefore pose a challenge to universal selection theory, it must be realized that such mechanisms of knowledge acquisition are quite limited in what they can accomplish. As already noted, Pavlovian conditioning does not account for the learning of new responses and the development of new perceptual abilities, but instead can account only for the association of old responses to new stimuli. And these new stimuli must be ones that immediately precede the unconditional stimuli. Stimuli that either follow or are presented long before the unconditional stimulus do not readily become conditional stimuli, at least not in nonhuman animals.

So Pavlovian conditioning may be an instructionist mechanism for attaching new meanings to old stimuli, but it cannot by itself provide innovative solutions to problems the way that natural selection and other selectionist processes have done and can do. Similarly, simulated nonstochastic neural networks may be capable of certain forms of learning without making use of cumulative blind variation and selection, but they are thereby condemned to sticking to their "innate" architecture and do not have the flexibility to reorganize themselves as demanded by novel problems in the way that evolutionary algorithms can. (Of course, it is the human researcher who changes them, using cumulative blind variation and selection, when it is clear that such networks have to be fine-tuned or more drastically overhauled.) Instructionist processes may play an important part in certain contexts for acquiring new knowledge, but they clearly cannot be the whole answer. And if they are effective, this in itself constitutes a puzzle of fit that must be ultimately accounted for, most likely by a selectionist explanation.

Finally, selection theory is not intended to account for changes that are not characterized by increases in adapted complexity. It is possible that a species may change over time in ways that are essentially neutral or perhaps even maladaptive. A decrease in the ozone layer may result in increased rates of radiation-induced mutations so that a species may no longer be able to preserve and pass down the accumulated wisdom of its genome. For various social, geographical, and economic reasons a society may lose adapted cultural and scientific knowledge; book burning and persecution of scientists occurred many times during periods of social conflict and upheaval. It is, of course, interesting to consider just how much evolutionary, cultural, scientific, and cognitive change is adaptive, and a comprehensive study of any of these fields will certainly have to go beyond selection theory. But to the extent that adaptive change has occurred, a selectionist perspective would see that cumulative blind variation and selection must be involved. To the extent that no change occurs or that change is not adaptive, other mechanisms (or factors interfering with cumulative blind variation and selection) must be involved. Selection theory is neither able nor intended to explain stasis or neutral or maladaptive developments, and to criticize it on this count indicates a misunderstanding of its intent.

But although it is neither able nor intended to explain neutral or maladaptive change, it can provide clues for understanding such processes, especially when adaptive change would be desired or normally expected. For example, despite continued attempts by breeders, no cattle have yet been developed that reliably produce significantly more female than male offspring.[27] Since these breeders have been successful in selecting for other traits such as increased milk production, selection theory suggests that there is no heritable genetic variation for the sex ratio of offspring. As we saw in chapter 10, cultures may fail to continue to adapt to changing environmental conditions. Selection theory would lead us to place the blame in such cases on lack of variation in cultural practices (perhaps no innovations are permitted by the society) or lack of information with which variations could be compared and selected.[28] And a school or classroom that is ineffective in fostering the growth of students' knowledge and skills would be suspected of not providing an educative environment that was both sufficiently free to allow students to generate and try out their variations, and responsive in giving sufficient feedback for students to select the better ones.

To return to what selection theory is intended to explain, it was observed that:

> None of Campbell's critics have proposed rival models of how knowledge could have arisen out of ignorance, or how stupid processes could lead to intelligent adaptation. In rejecting Campbell's Dictum the critics have all noted that advances in knowledge are all based upon prior knowledge, but . . . this is largely an irrelevant criticism. In any situation in which the advances in knowledge are not wholly explicable in terms of previously attained knowledge, a BVSR [blind variation and selective retention] process must be at work. Unless of course, we really do live in a world in which prayer or meditation or passive induction can lead directly to new knowledge without any need for blind trials.[29]

So despite the many attacks on selection theory, no one has yet demonstrated how a process that completely circumvents blind variation and selection can generate new knowledge. This, of course, does not mean that such a demonstration may not be forthcoming. But until such time, selection theory appears to be the only ballgame in town.

The Innatist Misconstrual of Selection

Unfortunately, a rather serious problem has arisen from the use of within-organism selectionist explanations of fit. Some quite prominent scholars have used selectionism to advance innatist conclusions concerning the ontogenetic achievement of puzzles of fit that are inconsistent with selectionist processes and products. This misconstrual involves emphasizing the process of selection while ignoring or deemphasizing the generation of novel variants among which selection takes place.

The work of cognitive scientist Massimo Piattelli-Palmarini is one such example.[30] Piattelli-Palmarini, who has written on concept and language acquisition, makes many strong arguments against instructionist (which he calls "instructive") accounts of concept and language acquisition and for a selectionist (his "selective") one. He is also impressed by the selectionist functioning of the mammalian immune system and uses this (as I did in chapter 4) to demonstrate both that somatic, ontogenetic selection processes do take place, and how theories of immunology have progressed from instructionist ones to a selectionist process.

But Piattelli-Palmarini's perspective on within-organism selection is quite different from the one advanced here in that his requires all variations to be innately provided before selection can take place. For example, in his 1989 discussion of the selectionist functioning of the immune system he mentions only in passing the somatic (ontogenetic) genetic reshuffling and mutations that provide the necessary variation in antibodies. And despite the fact that these antibodies are not specified in the genome but rather emerge from the countless possibilities that the genome allows, he refers to this as "the innate repertoire of antibodies."[31] He thus leads the reader to surmise that all possible antibodies are innately specified and therefore provided before any selection takes place. In so doing, he essentially resurrects the long-dead, genetically providential germ-line theory of antibody production proposed by Ehrlich in 1900 (see chapter 4). Piattelli-Palmarini makes the same basic argument for concept and language acquisition in stating that "*Any* pattern is *already* in the actual repertoire of the organism." [32]

This innatist (and therefore genetically providential) perspective on selectionism ignores the fact that in the evolution of species and in the production of antibodies *unpredictable novelty emerges* from the blind recombination and mutation of DNA sequences in the genes regardless of the fact that it is always the same old four genetic building blocks that are reshuffled. Indeed, immunologists now make an important distinction between what they call innate immunity and adaptive immunity, with the latter clearly not innate.[33] Similarly, a selectionist account of human cognition should lead to an expectation of novelty in the emergence of human concepts, ideas, and problem solving, dependent on the blind variation and selection of neuronal connections as discussed in chapter 5. But for Piattelli-Palmarini (and also for Fodor, as observed in chapter 11), all such products of human cognition must be innately specified before they can be selected, despite the fact that such a conclusion is inconsistent with what is now known of the immune system, that is, all antibodies are not innately specified in the genome but rather exist only as potentialities, the majority of which remain unrealized. It is also inconsistent with what is known about biological evolution.

Compare a typical adult human with a typical adult mouse. I will take it as uncontroversial that the human possesses knowledge of the world, concepts, and language that the mouse does not. And yet remarkably "an estimated 99 percent or more of the genes in mice and humans are the same and serve the same purpose."[34] So mouse genes are very much like human genes, differing only in the sequence of relatively few nucleotide base pairs and how these are organized into chromosomes, with a meager 1% of genes that humans do not share with mice (and perhaps also differences in how the genes are organized) responsible for human cognition and language. Now by Piattelli-Palmarini's (and Fodor's[35]) reasoning, we would have to consider the mouse as having innate knowledge of human concepts and language (the genetic building blocks are all there; they just need to be rearranged a bit). Such a conclusion would of course be absurd. The confusion here appears to stem from not appreciating that the recombinatory shuffling of genes, as well as the recombination of synapses, computer algorithms, and parts of molecules, can result in the emergence of completely novel and unpredictable possibilities for adapted complexity.

Here are two more examples.[36] Shakespeare's play *Macbeth* is essentially a long, ordered string of about 35 typographical characters, including the 26 letters of the English alphabet (ignoring the difference between upperand lower-case letters), a few punctuation marks, and spaces between words. Knowledge of these written characters, however, does not in itself provide any knowledge whatsoever about the play. Nor does knowledge of all the sounds of Russian provide any clues as to what Boris Yeltsin said yesterday. It should be clear that possessing the elements that make up a complex structure is not the same as knowing the complex structure itself.

Piattelli-Palmarini is not the only well-known scholar to misconstrue selectionism as requiring innately provided variations among which to choose. In a recent selectionist attempt to understand the workings of the human mind and brain, neurobiologist Michael Gazzaniga made the same innatist error in his book *Nature's Mind*. Although Gazzaniga, unlike Piattelli-Palmarini, does recognize that the generation of antibodies involves the somatic mutation of lymphocyte cells, the creative and variation-generating aspect of selection theory is not included in his view of human behavior and brain function. This oversight is made clear when he states "for the selectionist, the absolute truth is that all we do in life is discover what is already built into our brains"[37] and "selection theory is hard on the nature/nurture issue in arguing that all we are doing in life is catching up with what our brain already knows. We are discovering built-in capacities."[38] As one reviewer remarked, Gazzaniga's perspective on knowledge is not unlike Socrates' providentialist doctrine of recollection (or *anamnesis*; see chapter 6) in which "all knowledge is already in the mind, waiting to be remembered appropriately. Michael Gazzaniga's doctrine is remarkably similar, although it says, `selected' rather than `remembered'."[39]

A quick comparison of mouse and human (or amoeba and mouse) makes it evident that the among-organism selection of biological evolution results in the emergence of new possibilities that were not present before, and that natural selection is therefore a creative process that constantly fashions innovative variations among which to select. We should therefore expect within-organism ontogenetic selection to do the same. Indeed, as we saw in chapter 5, the brain not only selects from preexisting neural circuits, but actually engineers new circuits by first adding new synaptic connections between neurons and then selecting some while eliminating others. And although the mechanisms for such within-organism variation and selection may be considered innate, its products cannot be regarded as such, since by the same reasoning, one would be obliged to conclude that the genetic information for the human body, brain, and cognitive abilities was already contained in the very first organism that used DNA for its genes.

Gazzaniga and Piattelli-Palmarini are right in contending that selection theory has important implications for the nature-nurture debate in psychology. But they err in their conclusions that the implications are necessarily innatist. If they were right, selection could operate only among already achieved variations, and that would mean that we could not have evolved to be what we are today.

As Immanuel Kant noted: "The Creation is never over. It had a beginning but it has no ending. Creation is always busy making new scenes, new things, and new Worlds."[40] In the same way that natural selection among organisms provides an explanation for the continuing adapted complexity and adaptive creativity of organic evolution, cognitive selection within the nervous system provides an explanation for the adapted complexity and continuing adaptive creativity of the human mind.

[1]Jerne (1967, p. 204).

[2]Changeux (1985, pp. 279-281).

[3]Monod (1971, pp. 112, 113). Monod (1910-1976) shared the Nobel prize for physiology or medicine in 1965 for his work on messenger RNA and operator genes.

[4]Darwin (1860/1952, p. 239).

[5]At a deeper level, such a theory could, of course, be selectionist if it recognized that the antibody-specific information in the genome had been achieved through biological evolution.

[6]Wilson (1975, 1978).

[7]Changeux has also noticed the reoccurring sequence of instructionist (his "in-structive") theories preceding selectionist (his "selective") ones as indicated in the epigraph at the beginning of this chapter.

[8]Gunther Stent remarked of Edelman's writing: "I consider myself not too dumb. I am a professor of molecular biology and chairman of the neurobiology section of the National Academy of Sciences, so I should understand it. But I don't" (quoted in Johnson, 1992, p. 22).

[9]Since switching from immunology to the neurosciences, Edelman has been a prolific writer, publishing books in 1987, 1988 (two), 1989, and 1992.

[10]Vincenti (1990, p. 246).

[11]Thagard (1988, p. 103).

[12]Powers, who has provided what is arguably the only working model of purposeful human behavior, does not hesitate to invoke blind variation to explain how individuals are able to develop new control systems to control new aspects of their environment that they could not control before. "This is what I assume to be the basic principle of reorganization, which I could not put any better than Campbell did. Act at random, and select future actions on the basis of the consequences" (Powers, 1989, p. 288).

[13]Campbell (1977, p. 506).

[14]See Stein & Lipton (1989) for a comparison of such heuristic constraints in the development of science to preadaptations (exaptations) in biological evolution.

[15]Gamble (1983, p. 358).

[16]Thagard (1988, p. 107).

[17]Thagard (1988, p. 108).

[18]Hull (1988b, p. 476).

[19]Campbell (1977, p. 506).

[20]Gould claimed that ". . . cultural evolution is direct and Lamarckian in form: The achievements of one generation are passed by education and publication directly to descendants" (1991a, p. 65).

[21]Dawkins (1982) stated that "complex and elaborate adaptive fits can be achieved by instruction, as in the learning of a particular human language" (p. 173). Chapter 11 of this book argues otherwise.

[22]Hull (1988b, p. 453).

[23]It could be said, however, that since no task is ever exactly the same on different occasions, some variation and selection is always required since old knowledge must be continually adapted to new situations.

[24]Gamble (1983, p. 358).

[25]See, for example, Bradie (1986).

[26] The discussion here assumes that Pavlovian conditioning is an instructionist process, but there are some reasons to question such an interpretation. Let us examine some of these briefly. Of all the sensations taking place during the presentation of the first neutral then conditional stimulus, only one or a few may turn out to be reliable indicators of the impending unconditional stimulus. In the example just given, many things may happen immediately before the dark acidic liquid is placed in the dog's mouth--footsteps are heard; a researcher appears; liquid is poured from a large jar into a small beaker; a small amount is sucked up into a pipette; the researcher comes very close to the dog; the pipette is placed in the dog's mouth; and the acid is finally released. Which of these many stimuli can the dog use as a reliable indicator of the impending acid? There may well be some selection going on here, with the dog "jumping to conclusions" concerning the conditional stimulus and ultimately rejecting those conclusions that are not reliable. Selectionism may also be involved in the "blooming and pruning" of neurons that accompany such learning as discussed in chapter 5.

[27]See Maynard Smith (1978).

[28]See Popper (1966) for a discussion of the necessity of an open society for the continued improvement of government policies.

[29]Gamble (1983, pp. 359, 360).

[30]Piattelli-Palmarini (1986, 1989).

[31]Piattelli-Palmarini (1989, p. 17).

[32]Piattelli-Palmarini (1986, p. 127; emphasis in original).

[33]See Janeway (1993).

[34]Capecchi (1994, p. 52).

[35]See, for example, Fodor (1975, pp. 79-97).

[36]These two examples are similar to ones suggested to me by Paul Bloom.

[37]Gazzaniga (1992, p. 2).

[38]Gazzaniga (1992, p. 134).

[39]Tononi (1994, p. 298).

[40]Kant (quoted in Weiner, 1994, p. 3). Óú È8ßZ•Ú£L:¦¬Â8G[4H¯cÊ'ZÐÅ£ÚÈE€€œG°â',‡ÒT~‹²ø'@®
‰8½!DÊ¨–¢¨nÁnèØþ¾Nò…¡QWT3]×T¨«Ûï!±r0Z°ôÜyíÆÆ¦û…Aò•£YÎ.Ÿçõ£uÈ™ÆöÏ
±¶,ßtn©ÊîÊ§ÖA¶*ý…›ªv DFJÊ–ìƒ˜Æ)Xä–ÕývN8æ °-ì:°ùÏËê'' ,EèÇ[9x ê±cZcò/l¦m ~ÒnCù6´s!
øw»š¯ùžfchîÓ0€´'ËÑÏŠ¿z,UƒÌª‹Ç0˜›G&ƒ'iQÎmÆAGÞ*Ü.n