The Dialectical Biologist

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Introduction

THE VIEW of nature that dominates in our society has arisen as an accompaniment to the changing nature of social relations over the last six hundred years. Beginning sporadically in the thirteenth century and culminating in the bourgeois revolution of the seventeenth and eighteenth, the structure of society has been inverted from one in which the qualities and actions of individuals were defined by their social position to one in which, at least in principle and often in practice, individuals' activities determine their social relation. The change from a feudal world in which cleric and freeman, when they engaged in an exchange, were each subject to the laws and jurisdiction of his own seigneur, to a world in which buyer and seller confront each other, defined only by the transaction, and both subject to the same law merchant; from a world in which people were inalienably bound to the land, and the land to people, to a world in which each person owns his or her own labor power to sell in a competitive market—this change has redefined the relation between the individual and the social.

The social ideology of bourgeois society is that the individual is ontologically prior to the social. Individuals are seen as freely moving social atoms, each with his or her own intrinsic properties, creating social interactions as they collide in social space. In this view, if one wants to understand society, one must understand the properties of the individuals that "make it up." Society as a phenomenon is the outcome of the individual activities of individual human beings.

Inevitably people see in physical nature a reflection of the social relations in which their lives are embedded, and a bourgeois ideology of society has been writ large in a bourgeois view of nature. That view was given explicit form in the seventeenth century in Descartes's *Discours*, and we practice a science that is truly Cartesian. In the Cartesian world, that is, the world as a clock, phenomena are the consequences of the coming together of individual atomistic bits, each with its own intrinsic properties, determining the behavior of the system as a whole. Lines of causality run from part to whole, from atom to molecule, from molecule to organism, from organism to collectivity. As in society, so in all of nature, the part is ontologically prior to the whole. We may question whether in the interaction new properties arise, whether the "whole may be more than the sum of its parts," but this famous epistemological problem comes into existence only because we begin with an ontological commitment to the Cartesian priority of part over whole.

Cartesian reductionism is sometimes spoken of as the "Cartesian method," as a way of finding out about the world that entails cutting it up into bits and pieces (perhaps only conceptually) and reconstructing the properties of the system from the parts of the parts so produced. But Cartesianism is more than simply a method of investigation; it is a commitment to how things really are. The Cartesian reductionist method is used because it is regarded as isomorphic with the actual structure of causation, unlike, say, Taylor's or Fourier's series, which are simply mathematical fictions enabling one to *represent* a complex mathematical relationship as the sum of simple terms. Cartesian reduction as a method has had enormous success in physics, in chemistry, and in biology, especially molecular biology, and this has been taken to mean that the world is like the method. But this confusion of reduction as a tactic with reductionism as an ontological stance is like saying that a square wave is really the sum of a large number of sine waves because I can so represent it to an arbitrary degree of accuracy. In actual practice, reduction as a methodology and reductionism as a world view feed on and recreate each other. A reductionist methodology, like the analysis of variance, the most widely used and powerful statistical device in existence, assigns weights to the "main effects" of separate causes and then "first order," "second order," "third order"—and so on—interactions as a matter of tautological bookkeeping, like expanding a function in Taylor's series. Having performed this bit of number juggling, the natural (and the social) scientist then reifies these numerical components as objective forces with actual physical interactions (see Chapters 4, 5, and 6). The scientist then sets the stage for further analyses by the same method, since, after all, it has already been shown, by the previous analysis, that the main effects exist.

The great success of Cartesian method and the Cartesian view of nature is in part a result of a historical path of least resistance. Those problems that yield to the attack are pursued most vigorously, precisely because the method works there. Other problems and other phenomena are left behind, walled off from understanding by the commitment to Cartesianism. The harder problems are not tackled, if for no other reason than that brilliant scientific careers are not built on persistent failure. So the problems of understanding embryonic and psychic development and the structure and function of the central nervous system remain in much the same unsatisfactory state they were in fifty years ago, while molecular biologists go from triumph to triumph in describing and manipulating genes.

One way to break out of the grip of Cartesianism is to look again at the concepts of part and whole. "Part" and "whole" have a special relationship to each other, in that one cannot exist without the other, any more than "up" can exist without "down." What constitutes the parts is defined by the whole that is being considered. Moreover, parts acquire properties by virtue of being parts of a particular whole, properties they do not have in isolation or as parts of another whole. It is not that the whole is more than the sum of its parts, but that the *parts* acquire new properties. But as the parts acquire properties by being together, they impart to the whole new properties, which are reflected in changes in the parts, and so on. Parts and wholes evolve in consequence of their relationship, and the relationship itself evolves. These are the properties of things that we call dialectical: that one thing cannot exist without the other, that one acquires its properties from its relation to the other, that the properties of both evolve as a consequence of their interpenetration.

The Darwinian theory of evolution is a quintessential product of the bourgeois intellectual revolution. First, it was a materialist theory that rejected Platonic ideals and substituted for them real forces among real existing objects. Second, it was a theory of change as opposed to stasis, part of the nineteenth-century commitment to change, "a beneficent necessity" as Herbert Spencer called it. Evolutionism as a world view, the belief that all natural and social systems were in a constant state of change, was the general principle, of which organic evolution was only an example (and, historically, a late one at that). Both the commitment to materialism and the commitment to the universality of change are part of a dialectical view as well. But the third aspect of evolutionary theory, the metaphor of adaptation, is pure Cartesianism. For Darwin, organisms adapt to a changing external world which poses problems that the organisms solve through evolution. The organism and its environment have separate existences, separate properties. The environment changes by some autonomous process, while the organism changes in response to the environment, from which it is alienated. It is the organism as the alienated *object* of external forces that marks off the Cartesianism of Darwin from the dialectical view of organism and environment as interpenetrating so that both are at the same time subjects and objects of the historical process (see Chapters 1, 2, and 3).

When people speak of science, they mean different things. They may mean the method of science, the controlled experiment, the analytical logic, as in "it can be shown scientifically." Or they may mean the content of scientific claims about the world, the facts and theories that the scientific method has produced, as in "It's a scientific fact." Or they may mean the social institution of science, the professors, universities, journals, and societies by which people are organized to carry out the scientific method to produce the scientific facts, as in "making a career in science." No one will argue that science as institution is not influenced by social phenomena like racism or the structure of social rewards and incentives. Many people will now admit that the problematic of science—what questions are thought to be worth asking and what priority will be awarded them—is also strongly influenced by social and economic factors. And everyone agrees that the findings of science, the facts, may have a profound effect on society, as best shown by the atomic bomb.

But nothing evokes as much hostility among intellectuals as the suggestion that social forces influence or even dictate either the scientific method or the facts and theories of science. The Cartesian social analysis of science, like the Cartesian analysis in science, alienates science from society, making scientific fact and method "objective" and beyond social influence. Our view is different. We believe that science, in *all* its senses, is a social process that both causes and is caused by social organization. To do science is to be a social actor engaged, whether one likes it or not, in political activity. The denial of the interpenetration of the scientific and the social is itself a political act, giving support to social structures that hide behind scientific objectivity to perpetuate dependency, exploitation, racism, elitism, colonialism. Nor do absurd examples diminish the truth of this necessary engagement. Of course the speed of light is the same under socialism and capitalism, and the apple that was said to have fallen on the Master of the Mint in 1664 would have struck his Labor Party successor three-hundred years later with equal force. But whether the cause of tuberculosis is said to be a bacillus or the capitalist exploitation of workers, whether the death rate from cancer is best reduced by studying oncogenes or by seizing control of factories—these questions can be decided objectively only within the framework of certain sociopolitical assumptions. The third section of the book is not about the effect of science on society or the effect of society on science. Rather, it is meant to show how science and other aspects of social life interpenetrate and to show why scientists, whether they realize it or not, always choose sides.

ONE

On Evolution

1

Evolution as Theory and Ideology

This chapter was first published as "Evoluzione" in *Enciclopedia Einaudi*, vol. 3, edited by Giulio Einaudi (Turin, Italy, 1977). A long section on the principles of evolutionary genetic change has been omitted here. The present text is the English original, which was translated into Italian for the encyclopedia.

THE IDEOLOGY OF EVOLUTION

Although the concept of evolution has become firmly identified with organic evolution, the history of living organisms on earth, the theory of the evolution of life is only a special case of a more general world view that can be characterized as "evolutionism." The ideology of evolutionism, which has developed in the last two hundred years, has permeated all the natural and social sciences, including anthropology, biology, cosmology, linguistics, sociology, and thermodynamics. It is a world view that encompasses the hierarchically related concepts of change, order, direction, progress, and perfectability, although not all theories of evolutionary processes include every successive step in the hierarchy of concepts. Theories of the evolution of the inorganic world, like cosmology and thermodynamics, generally include only change and order, while biological and sociological theories add the ideas of progress and even perfectability as elaborations of their theoretical structure.

Change

All evolutionary theories, whether of physical, biological, or social phenomena, are theories of change. The present state of a system is seen as different from its past states, and its future states are predicted to again differ from the present. But the simple assertion that past, present, and future differ from one another is not in itself an evolutionary world view. Before the widespread acceptance of evolutionary ideas in the nineteenth century, it was recognized that changes occur in natural and social systems, but these changes were regarded as exceptional alterations in a normally stable and static universe. The myth of the Noachian flood, by which God intervened to destroy the living world, only to repopulate it again from a handful of living beings especially preserved for that purpose, was the prototype of a general, nonevolutionary theory of change. The world had been specially created in both its natural and social form by the will of God, and the organization of the world was a manifestation of that divine will. On occasion the state of the world underwent an alteration, but such a change was abnormal, the result of divine intervention in an otherwise unchanging universe. The increasingly frequent discovery of fossils in the eighteenth and nineteenth centuries made it apparent that new forms of life had appeared at various epochs and that old forms had died out.

William Buckland's (1836) response to these discoveries was characteristic: "In the course of our enquiry, we have found abundant proofs, both of the Beginning and the End of several successive systems of animal and vegetable life; each compelling us to refer its origin to the direct agency of Creative Interference; 'We conceive it undeniable that we see, in the transition from an Earth peopled by one set of animals to the same Earth swarming with entirely new forms of organic life, a distinct manifestation of creative power transcending the operation of known laws of nature.' " The Noachian flood was generalized to a succession of floods in the theory of diluvianism, which was in turn part of the general theory called catastrophism, which included both floods and inundations by lava from periodic volcanic activity. In the domain of social organization, it was assumed that classes were fixed in their relations by divine will but that occasional changes in the social status of individuals could occur as the result of the withdrawal or conferral of grace either by God or his earthly representatives. Charles I ruled *dei gratia*, but as Oliver Cromwell observed, God's grace was removed from him, as evidenced by his severed head.

There is no fundamental difference between a theory that the world was populated once by an act of special creation and one that postulates several such episodes. All theories of change by the occasional intervention of a higher power or extraordinary force in an otherwise static universe stand in direct opposition to the evolutionary world view, which sees change as the regular and characteristic feature of natural and social systems. In this uniformitarian view, the only unchanging features of the universe are the laws of change themselves. Uniformitarianism was first introduced into geology by James Hutton in 1785 and expanded by Sir Charles Lyell in his *Principles of Geology* (1830). According to the uniformitarian view, the geological processes of mountain building and erosion, which are responsible for the present features of the earth, have been at work ever since water in appreciable quantities has been present, and will continue to operate throughout the history of the earth with the same geotectonic consequences.

The theory of organic evolution assumes that the processes of mutation, recombination, and natural selection have been the driving forces since the beginning of life, even before its organization into cells, and that these forces will continue as a characteristic feature of living organisms until the extinction of the living world. It is assumed that life in other parts of the cosmos will exhibit these same dynamic features. A commitment to the evolutionary world view is a commitment to a belief in the instability and constant motion of systems in the past, present, and future; such motion is assumed to be their essential characteristic. In the eighteenth century this belief was expressed for the nascent bourgeois revolution by Diderot: "Tout change, tout passe, il n'y a que le tout qui reste" (everything changes, all things pass, only the totality remains) [1830] 1951, p. 56). In the nineteenth century Engels expressed the socialist revolutionary ideology: "Motion in the most general sense, conceived as the mode of existence, the inherent attribute, of matter, comprehends all changes and processes occurring in the universe, from mere change of place right up to thinking" ([1880] 1934, p. 69).

The growth in the ideology of change as an essential feature of natural systems was the necessary outcome of that slow but profound alteration in European social relations that we call the bourgeois revolution. The replacement of hereditary holders of power by those whose power derived from their entrepreneurial activities demanded an alteration in legitimating ideology from one of natural stasis and stability to one of unceasing change. The breaking down of the last vestiges of feudal society, in which peasant and lord alike were tied to the land; the ascendancy of merchants, financiers, and manufacturers; the growing power in France of the *noblesse de la robe* in parallel to the old *noblesse de l'épée*—all were in contradiction with a world view that saw changes in state as only occasional and unusual, the result of irregular reallocations of grace. Reciprocally, a world view that made change an essential feature of natural systems was inconceivable in a social world of fixed hereditary relations. Human beings see the natural world as a reflection of the social organization that is the dominant reality of their lives. An evolutionary world view, being a theory of the naturalness of change, is really congenial only in a revolutionizing society.

Order

Although change is a necessary feature of evolutionary ideology, it has not seemed sufficient to most evolutionary theorists. If a deck of cards is shuffled over and over, the sequence of cards changes continually, yet in some sense nothing is happening. One random sequence of cards is much like another, and successive states of the deck cannot be described except by enumerating the cards. For Bergson and Whitehead, for example, no evolution is occurring because there are only successive states of chaos, while an evolutionary process must give rise to new states of organization. In *Science and the Modern World*, Whitehead wrote: “Evolution, on the materialistic theory, is reduced to the rôle of being another word for the description of changes of the external relations between portions of matter. There is nothing to evolve, because one set of external relations is as good as any other set of external relations. There can merely be change, purposeless and unprogressive” ([1925] 1960, p. 157).

Nearly all evolutionary theories attempt to describe the outcome of the evolutionary process in terms of an ordered scale of states rather than simply as an exhaustive list of attributes. For example, organisms are described as more or less complex, more or less homeostatic, of different degrees of responsiveness to environmental variation in their physiology or development. In this way the changes in the system, which might require a very large number of dimensions to enumerate, are reduced to a scale of much lower dimensionality. At the same time the unordered, extensive descriptions of the system become ordered descriptions along a scale of complexity, homeostasis, environmental buffering, and so on.

A major problem of evolutionary theories is to decide on the scales that the evolved states of a system are to be ordered along. One form of evolutionary ecology is the theory of succession, which asserts that over relatively short periods of time, of the order of generations, the species composition of a community of organisms will undergo predictable changes. In specific regions this succession can be described simply by listing the plant species and noting their relative abundance at successive stages. In New England an abandoned farm field is first occupied by various herbaceous weeds, then by white pines; later the white pines give way to beeches, birches, maples, and hemlocks. This description is nothing but a list of changes. Attempts have been made to introduce order into the theory of succession by describing, among others, changes in (1) the total number of species; (2) species diversity, taking account both of the number of species and of their relative abundance; (3) biomass diversity including both the physical size of each species and its relative abundance; or (4) the ratio of total rate of production of living material to the total standing crop of material. None of these measures contains the actual list of species or their unique qualities, but rather establishes a single quantitative dimension along which community compositions can be ordered. There is, however, no a priori criterion for deciding which of these, if any, is a “natural” or even an empirically useful dimension. To choose among them it would be necessary to have a kinematic description of the evolution of the community that could be phrased in terms of the chosen dimension. That is, given some set of dimensions that describe the state of the system, $E(t)$ at time t, it must be possible to give a law of transformation, T, that will carry $E(t)$ into $E'(t+1)$: $E'(t+1) = T[E(t)]$.

But the search for a law of transformation cannot be carried out without some idea of the appropriate dimensions of description of the system, since there is no assurance that one can find a law by beginning with an arbitrary description. The development of a law of evolutionary transformation of a system and of the appropriate dimensions of description is a dialectical process that cannot be carried out by a priori assumptions about either law or description. In evolutionary ecology rather little progress has been made in this process precisely because the ordered states of description of communities have been chosen arbitrarily for their intuitive appeal rather than by any constructive interaction with the building of a kinematic theory. Evolutionary genetics has been more successful in building kinematic theories of evolutionary change, but only because it has given up the attempt to introduce an ordered description. Evolutionary or population genetics has an elaborate theory of the change in the frequency of genes in populations as a consequence of mutations, migrations, breeding structure of populations, and natural selection. But this theory is framed entirely in terms of an extensive list of the different genetic types in the population and how that list changes in time. Every attempt to find some ordered description of a population, as for example its average size, its reproductive rate, or the average fitness of individuals in it, whose transformations over time can be described by a kinematic law, has failed. Thus when the population geneticist Dobzhansky, described evolution as "a change in the genetic composition of populations" (1951, p. 16), he did so *for lack of anything better.* Described in this way, evolution is nothing but the endless reshuffling of the four basic molecular subunits of DNA.

The requirement of order marks the division between the purely mechanistic descriptions of evolutionary processes, as represented by Dobzhansky's dictum, and those with some metaphysical element, leading in the extreme to the creative evolutionism of Bergson and Teilhard de Chardin. To assign the successive states of an evolutionary sequence to some order requires a preconception of order, a human conception that is historically contingent. In the case of the deck of cards, all sequences are equally probable, so any given completely mixed hand at poker has exactly the same probability as a royal flush; yet we are surprised (and rewarded) when a royal flush appears. Ideas of order are profoundly ideological, so the description of evolution as producing order is necessarily an ideological one. In this sense evolution is neither a fact nor a theory, but a mode of organizing knowledge about the world.

Direction

If an ordered description of the states in an evolutionary process has been created, it becomes possible to ascribe a temporal direction to evolution.

Evolutionary processes are then described as the unidirectional increase or decrease of some characteristic. In one form of evolutionary cosmology the universe is said to be constantly expanding; in thermodynamics entropy increases. In evolutionary ecology it has been variously asserted that complexity, stability, or the ratio of biomass to productivity increases in time and that species diversity decreases or increases toward an intermediate value. In evolutionary genetics the reproductive rate of the population, its average size, and its average fitness have all been proposed as monotonically increasing with time, while for the evolution of life over geological time, it has been suggested that organisms are becoming more complex and more physiologically homeostatic. The history of human culture is described not simply in terms of the change from hunting and gathering to primitive agriculture, from feudal agriculture to capitalist industry. Instead, the modes of organization of production are placed on a graded scale as, for example, the degree of division of labor (Durkheim) or the degree of complexity (Spencer). Only historical geology has been largely free of a theory of monotonic evolution. The processes of orogeny and erosion by which mountains are raised and then slowly leveled by wind and water into a flat, featureless plain, only to be raised again in another oro-genic episode, form a repeated cycle with no general direction. Glacial and interglacial periods cyclically follow each other, causing the raising and lowering of sea level and a long cycle of temperature change. The recent theory of plate tectonics, according to which lava wells up to the earth's surface along major cracks under the ocean, is also cyclic, since the spreading of the sea floor causes the opposite edges of the major lithospheric plates to slip downward (subduction) into the earth interior, where the material is again melted down. It is assumed that the total amount of the earth's crust remains more or less constant in the process. Of course, in the very long term, the earth as a whole must cool, and all geotectonic processes must eventually come to an end, but the extremely long time scale of this prediction takes it out of the domain of geology proper, displacing it to the borderline with cosmology and thermodynamics, which have their own general theories of directionality.

The search for a direction in evolution is closely linked with the postulation of order. Indeed, the choice of the appropriate ordered description of evolutionary states is largely the consequence rather than the precursor of decisions about direction, although in some few cases the description of an evolutionary process as unidirectional along some set of ordered states may simply be a restatement of the underlying dynamic equations of the process. In classical physics the laws of the motion of bodies can be restated, by changing the parameters, as laws of the minimization of potential energy. Even more generally, movements of bodies and classical optics can both be subsumed under Fermat's principle of least action, and nineteenth-century physics textbooks were sometimes cast in these terms.

Borrowing from this tradition in physics, evolutionists have looked for ways to parameterize the equations of population ecology or population genetics so that they will appear as maximization or minimization principles. Fisher's fundamental theorem of natural selection (1930), showing that the average fitness of a population always increases, was such an attempt. Unfortunately the theorem turned out to be somewhat less "fundamental" than claimed since it applies only in specially restricted cases. In like manner ecologists have attempted to find in the equations of species interactions principles of minimization of unused resources or maximization of efficiency but, like Fisher's fundamental theorem, such restatements apply only in special cases. When such principles have been stated, the mathematical result has been reified, and the consequent claims about the material world have often been confused or incorrect. The principle that the genetic changes in a population under natural selection result in an increase in the mean fitness of the population, even in the special circumstances where it is true, is only a statement about the *relative* fitnesses of individuals within the population and makes no prediction at all about the absolute survival and reproduction of the population. In fact, after undergoing natural selection a population is not likely to be more numerous nor to have a higher reproductive rate than before; it may even be smaller and have a lower reproductive rate. Yet the principle of the increase of relative fitness has been reified by evolutionists who suppose that species become, in some sense, *absolutely* more fit by natural selection (see Chapter 2).

More often the kinematic equations of evolutionary processes cannot be recast in terms of a directional change in some intuitively appealing ordered variable or, even more often, no kinematic equations exist for the process. Among all evolutionary processes only genetic evolution within populations and statistical thermodynamics have well-founded mathematical structures. Other domains, such as evolutionary ecology, are highly mathematized, but the dynamics on which their mathematical structures are based are entirely hypothetical, and thus their theories are elaborate fictions, which nevertheless may contain many truths. In the absence of an exact theory of evolution, directions are ascribed to evolutionary processes a priori, based on preexisting ideological commitments.

The scale most often appealed to is *complexity*. It is supposed that during organic and social evolution organisms and societies have become more complex. Spencer (1862) in his *First Principles* declared that the evolution of the cosmos, of organic life, and of human society all progress from the homogeneous to the heterogeneous, from the simple to the complex. Modern evolutionists largely agree. Vertebrates, and mammals in particular, are regarded as more complex than bacteria, and since the vertebrates evolved later than single-celled organisms, complexity must have increased. The brain is thought to be the most complex organ, so the human species, with its exceedingly complex brain, must represent the most advanced stage in evolution. Closely tied to the idea of increasing complexity is the theory that modern organisms contain more information about the environment than primitive ones, information stored during the evolutionary process in the complex structures of advanced species. Finally, the supposed increases of information and complexity are regarded as exceptions to the second law of thermodynamics, which requires a general increase in entropy and homogeneity, with a decrease in complexity by randomization. Evolutionists speak of the accumulation of "negentropy," of complexity and information, as the unique property of living systems, marking them off from the inorganic.

The supposed increase in complexity and information during evolution does not stand on any objective ground and is based in part on several confusions. First, how are we to measure the complexity of an organism? In what sense is a mammal more complex than a bacterium? Mammals have many types of cells, tissues, and organ systems and in this respect are more complex, but bacteria can carry out many biosynthetic reactions, such as the synthesis of certain amino acids, that have been lost during the evolution of the vertebrates, so in that sense bacteria are more complex. There is no indication that vertebrates in general enter into more direct interactions with other organisms than do bacteria, which have their own parasites, predators, competitors, and symbionts. And even if we are to accept sheer structural variation as an indication of complexity, we do not know how to order it, not to speak of assigning a metric to it. Is a mammal more complex structurally than a fish? Yet 370 million years passed between the origin of the fishes at the end of the Cambrian and the first mammals at the beginning of the Cretaceous. If one starts with the assertion that structural complexity has increased, it is possible to rationalize the assertion a posteriori by enumerating those features, for example, a very large hindbrain, that appear later in evolution and declaring them to be more complex. The evident circularity of this procedure has not prevented its widespread practice.

A second difficulty with complexity as a direction in evolution arises from the confusion of modern "lower organisms" with ancestral organisms. Modern bacteria are not the ancestors of modern vertebrates, they are the product of more that a thousand million years of cellular evolution. While structurally more complex forms may have appeared later in the evolutionary sequence and evolved from less complex ones, they have not replaced the less complex but coexist with them. Evolution cannot be the change from less to more complex *in general*, because that description says nothing about the millions of years of evolution within grades of organization. The same confusion exists in anthropology. Modern "primitive" people are not the ancestors of "advanced" civilizations, and we do not know what the social structure was in the prehistoric ancestral human groups. The Bushmen of the Kalahari have as long a history as any other human group, so the judgment that their society is less evolved than ours requires making an a priori decision about the succession of stages that are to be taken as a description of social evolution and postulating that some groups have become arrested in their social evolution. The scale of comparison then ceases to be a temporal sequence and becomes instead a contemporaneous scale ordered by time of first historical appearance. The difference between contemporaneous grades based on time of first appearance and strictly historical sequences marks off organic evolutionary theory from a social theory like historical materialism. Nothing in the theory of organic evolution demands the *replacement* of earlier grades by later grades of organization, and some strong theoretical reasons from ecology suggest that coexistence is to be expected. In contrast, Marxist historical theory predicts the eventual replacement of one mode of production by another universally, although for long periods different, contradictory modes may coexist.

A third difficulty is the equation of complexity with information. It is not at all clear how the information in a structure is to be measured. The only concrete suggestion for organisms is to regard the genes as a code made up of three-letter words with a four-letter alphabet, then calculating the information in the total genetic "message" for each organism by the Shannon information measure. However, by this measure many invertebrates turn out to have more information than many vertebrates, and some amphibia are more complex than *Homo sapiens*. The problem is that complexity and information have only a metaphorical, not an exact, equivalence. While it is appealing to speak of "information" about the environment being "encoded" in the structural and physiological complexity of organisms, such statements remain in the realm of poetry.

The confusion is further compounded by the relation of metaphorical notions of complexity and information to the second law of thermodynamics. "Entropy," which is the Greek equivalent of the Latin "evolution," was introduced in the nineteenth century as a property of the universe that is always increasing. In the original macroscopic form of thermodynamics, it meant simply that different regions of the universe become, in time, more and more alike in their mean energy levels, so less and less useful work can be derived from their interaction. The kinetic theory of gases and, later, statistical mechanics reinterpreted this principle to mean that in any defined region of space the kinetic energy of molecules would eventually have the same distribution as in any other region of space, because connections between the regions would lead to a randomization of the molecules and a redistribution of energies through collisions. Evolutionists have incorrectly interpreted this theory to mean that all molecules would have the same kinetic energy rather than that collections of molecules would have the same distribution of energies. Moreover, they have confused kinetic energy with gravitational and electromagnetic energy and have supposed that a general second law guarantees that all the molecules in the universe will eventually years. But such trends are in part an artifact of taxonomic practice, in part the result of the greater likelihood of finding more recent fossils, and in part the result of the breakup of the single large continent, Pangaea, beginning about 250 million years ago, which created a much greater diversity of marine habitats as a temporary historical fact. If the present continents drift together again, the diversity of marine mollusks will inevitably decrease. On the time scale of ecological rather than evolutionary changes, one finds both increases and decreases in diversity in the succession of species composition in temporarily disturbed terrestrial and aquatic environments. Certainly, no empirical generalization is possible. At the theoretical level the situation is even more extraordinary. Despite the repeated claim that greater complexity and diversity lead to greater stability, no rigorous argument has ever been offered in support of this theorem and, on the contrary, recent mathematical and numerical studies in both the theory of community ecology and in population genetics have shown exactly the opposite to be true. If complexity of a community is defined as the number of species interactions multiplied by the strength of the interactions, it has been shown that as this complexity increases, by adding more species or by increasing the strength of the interaction, the probability that the community will be stable to perturbation decreases rather than increases (May, 1973).

The emphasis on diversity, complexity, and stability as the trends in evolution can only be understood as ideological in origin. While change and motion were the intellectual motifs of the bourgeois revolution, as a legitimation of the overturning of old class relations, the consolidation of that revolution in the latter part of the nineteenth and in the twentieth century has required a different view, consonant with a newly stabilized society. Change had to be tamed in science as it was in society. The result has been an emphasis in modern evolutionary theories on dynamic stability. Although individual elements in the system are changing place, the system as a whole remains in a steady state; in the same way individuals may rise and fall in the social scale, but the hierarchy of social relations is thought to be unchanging. For social theorists the bourgeois revolution was the last step in a social evolution away from artificial and unstable hierarchies to a natural social structure based upon the free movement of individuals according to their innate abilities. The society that has been produced is one of great complexity, with an immense division of labor and very strong interactions among the component parts. Moreover, the stability of the modern social order is thought to be provided precisely by the complex interactions among the individual units, each dependent upon the others. The description of the evolution of biological systems is a mirror of the supposed evolution of modern bourgeois society. An ironic result of this view of evolution has been that the environmentalist movement of the present day has used the preoccupation with stability and complexity of natural communities of species to oppose the expansion of the very capitalist system of production that gave rise to the ideology originally.

In the twentieth century there has been a general change of emphasis from directionality to steady-state theories of evolution. In cosmology the perpetual-creation theories and the expansion-contraction theory postulate that the universe is in a long-term steady state or a cyclic oscillation. Thermodynamic theories allow that entropy may be increasing only locally in space-time. Theories of organic evolution are now entirely preoccupied with stability and dynamic equilibrium. The literature of theoretical evolutionary genetics and evolutionary ecology is almost totally taken up with finding the conditions of stable equilibrium of genes and species or with trying to distinguish different special theories of phenomena on the assumption that they are in stable equilibrium. The chief controversy in evolutionary genetics for the last thirty years has been whether the observed genetic variation among individuals is maintained by natural selection or is the consequence of repeated mutations of unselected genetic variants. Proponents of both schools depend upon elaborate mathematical analysis and statistical treatment of data on the assumption that populations in nature are in an equilibrium state, with no trace of their past histories. Like modern bourgeois social thought, modern evolutionary thought denies history by assuming equilibrium.

The emphasis on equilibrium must nevertheless accommodate the obvious fact that evolution continues to occur. There is no trace in the fossil record that the formation and extinction of species have ceased or even slowed down, and rates of morphological change within evolutionary lines remain high, even in the most recent fossil horizons. If evolution and adaptation continue to occur, how can the world be in a steady state? The answer given is that the environment is constantly changing, always decaying with respect to the current adaptation of species. In this view the continued evolution of organisms is simply keeping up with the moving, worsening environment, but nothing is happening globally. The environment worsens because resources are used up, because competitors, predators, and prey evolve, and because any change makes previous adaptations obsolete. No species can ever be perfectly adapted because each is tracking a moving target, but all extant species are close to their optima. Species become extinct if they evolve too slowly to track the moving environment or disperse too slowly to keep up geographically with their preferred environment. In this way modern evolutionary theory solves the apparent contradiction between the observation of continued evolution and the ideological demand that the assemblage of organisms be stable and optimal.

Progress

The view of nineteenth-century evolutionists was quite different. For them evolution meant progress, movement from worse to better, from inferior to superior. The idea of progress requires not only a theory of direction but also a moral judgment. Even if it were granted that organic evolution resulted in an increase in complexity, that trend would not be *progressive* unless some general theory of value made it so. The moralism in ideas of evolutionary progress is seldom made explicit but is usually hidden in the assumption that the human species represents the highest and best form of nature. Most modern evolutionists have tried to expunge anthropocentric moralism from their theories, but a few, such as Teilhard de Chardin, have reverted to nineteenth-century progressivism. For Teilhard de Chardin (1962), "Man is the only absolute parameter of evolution," by which he means not merely organic but *cosmic* evolution. This is an echo of Whitehead's (1938) division of occurrences in nature into six types, of which "human existence, body and mind" is the highest, other animals are next, plants the next, and so on down to atomic particles. Man leads all the rest. The shibboleths of progressivism are the superiority of man in the cosmos, of industrial man in the world economy, and of liberal democratic man in world society. We have, then, a kind of Whig biology, which sees all of evolution as leading to entrepreneurial man.

The most influential spokesman of evolutionary progress in the nineteenth century, Herbert Spencer, equated progress with change itself. Spencer claimed that: "From the earliest traceable cosmical changes down to the latest results of civilization, we shall find that the transformation of the homogeneous into the heterogeneous is that in which progress essentially consists" ([1857] 1915, p. 10). He believed that this transformation had occurred in the arts, in forms of political organization, in language, in economic relations, and in the history of organic life. But Spencer did not offer any other justification for the progressive quality of change. For him change of any sort and in any direction was by its nature progressive, "a beneficent necessity." The contrast between Spencer's belief in the intrinsic progressivism of change and the present belief in stability and dynamic equilibrium, with species fighting a rearguard action against a threatening environment, is the contrast between the optimistic, revolutionizing bourgeoisie committed to destroying the old restrictive social relations in the nineteenth century and an entrenched but embattled capitalism asserting its stability and permanence in the face of a deteriorating world situation in the twentieth.

There is another sense in which evolutionary sequences are regarded as progressive and in which the moralistic element comes directly from economic ideology. Darwin laid special emphasis on the "perfection" of organs like the eye, with its complex arrangements for focusing, varying the amount of admitted light, and compensating for aberration, as a severe test of his theory of evolution by natural selection. Evolutionary theory was meant to explain not only the manifest diversity of organisms, but also the obvious fact that the organisms showed a marvelous fit to nature. The concept of adaptation is that the external world sets certain "problems" for organisms and that evolution consists in "solving" these problems, just as an engineer designs a machine to solve a problem. So the eye is a solution to the problem of seeing; wings of flying; lungs of breathing. Putting aside the great difficulties of deciding what problem is posed by nature, or what problem a particular organ is a solution to (see Chapter 2), there is the question of deciding how good the solution is for a given problem. This requires a criterion of optimality, so one can judge how close to optimum the evolutionary process has brought the organism. Present evolutionary theory assumes that such optima can be specified for particular situations and that evolution can be described as moving organisms toward the optimal solutions. Because the problems are always changing slightly, no species is ever exactly at its optimum, but extant species have achieved near-optimal solutions and would improve their fit if the environment remained constant for a sufficient period. In fact, some forms of optimization theory, including the theory of games, have been taken over from economics and political science as techniques for prediction and explanation in organic evolution, replacing purely kinematic theories of population genetics and population ecology. In kinematic theories a few basic assumptions are made about the mechanics of inheritance or the elementary rules of population growth, a predictive mathematical or numerical machinery is constructed from these assumptions, and the trajectory of the process is predicted. Optimization theories have no kinematics. It is *assumed* that evolution carries a system to its optimum, the optimum is described, and the state of the system is compared to it.

Putting an optimization program into practice requires a general theory of optimality, which evolutionists have taken directly from the economics of capitalism. It is assumed that organisms are struggling for resources that are in short supply, a postulate introduced by Darwin after he read Malthus's *Essay on the Principle of Population*. The organism must invest time and energy to acquire these resources, and it reinvests the return from this investment partly in acquiring fresh supplies of resource and partly in reproducing. That organism is most successful which acquires the greatest net surplus for investment in successful reproduction. There are then two criteria of optimality. One is the expenditure of the least amount of energy for each unit of resource acquired and the other is the allocation of the largest proportion of acquired surplus to reproduction, subject to the requirement that sufficient surplus is available for new acquisition. In practice the criteria for these problems of optimum resource allocation are minimum time or maximum yield. An example is the problem of time allocation in birds that gather food and bring it back to the nest to be

Bleak House (1852) and made it the central theme *of Hard Times* (1854).

Biology was the last domain of intellectual life to incorporate the evolutionary world view, in part because it directly threatened ideas of the uniqueness and superiority of the human species. Nevertheless, the idea of organic evolution was widespread, if not dominant, before 1859. Charles Darwin's grandfather, Erasmus Darwin, published *Zoonomia* in 1794 and *The Temple of Nature* in 1803, which expressed romanticized but remarkable prescient views of the origin and evolution of life, including man. Between 1794 and 1830 in France, Lamarck and Geoffroy Saint-Hilaire developed theories of organic evolution that contradicted the powerful Baron Cuvier's attempt to explain the fossil record by repeated floods. Spencer, in 1857, argued for the evolution of life on the basis of the generality of the principle of evolution in every other domain. Darwin himself, in the third edition of *Origin of Species* in 1861, provided a historical sketch of the writings on organic evolution prior to his own.

Not only the intellectual realm, but the family and political milieu as well, reinforced the ideology of change and movement for Darwin. His maternal grandfather, Josiah Wedgwood, began as a poor apprentice and became a great industrial magnate, the very epitome of the new class of self-made industrialists. Darwin's paternal grandfather, Erasmus, a self-made man, belonged to the social circle of new midland industrialists that included Wedgwood, James Watt, James Keir, and Matthew Boulton. Charles's father took forty pounds of Erasmus's money and made himself well to do by his own activity, at a time when the high Tory prime minister was Robert Peel, grandson of a peasant turned peddler. Darwin set out on the voyage of the *Beagle* at the height of the agitation for the Reform Bill of 1832, and he had developed most of his ideas for *Origin of Species* by the time of the revolutions of 1848.

Darwinism and Materialism

The pervasiveness of evolutionism, resulting from the political economic revolution, led to a serious contradiction with an older intellectual tradition, inherited from Plato and Aristotle, that was consonant with the older static world order. This was the concept of the *ideal type*. According to this view, real objects in the world were imperfect manifestations of underlying ideal patterns. The ideals had no material form but could be glimpsed "through a glass, darkly" by studying real objects. The purpose of scientific study was to understand the ideal types, and the problem of science was to infer these types despite the imperfection of their manifestations in the world. A corollary of this typological approach is that the variation among objects of a given type is ontologically different from the variation among types. The differences among objects within a type are the result of "disturbances" which, although they may have some subsidiary intrinsic interest, are essentially a distraction, while the study of the types themselves will reveal the essential underlying structure of the universe. Newton's ideal bodies moving in empty space were examples of types that abstracted ideal motion from real motion, putting aside friction, inelasticity, and the occupation of finite space by mass in order to construct the "basic" laws of motion. Each species of living organism was regarded as a "type," and the actual individuals in nature were imperfect manifestations of the true species ideal. Even at present the type is still used in taxonomy; it is a single individual that is deposited in a collection and designated as the standard of comparison against which all other individuals thought to belong to the species are matched. Actual specimens vary from the type, and sometimes the type specimen turns out to be quite untypical of the species as a whole. Modern taxonomic practice has moved away from this tradition in part by designating *holotypes*, populations of specimens whose statistical properties are taken as representative of the species as a group.

The theory of ideal types established the problematic for pre-Darwinian evolutionary theory: how do organisms pass from one type to another or, alternatively, how can new types come into existence? The fact that all organisms were the offspring of other organisms made the problem even more difficult, since in the process of continuous reproduction some instant must mark the passage of living material from one type to another, or at some instant a new type must come into existence and be represented by a material form that at the previous moment had belonged to a different type. Two general solutions to this dilemma were offered, neither of which could be satisfactory from either a physical or a metaphysical standpoint. Lamarck's theory was that organisms changed type slowly by the accretion of small differences during the individual's lifetime. Thus the giraffe stretched its neck to feed on higher leaves, the offspring of this giraffe would have a slightly longer neck, which would in turn stretch to reach still higher leaves, and so on over time. The transformation occurred because the animal sensed the need for more food, and this need instituted a change in form that was an adaptive response. The resultant change had to be incorporated into the heredity of the organism. Since plants were not regarded as having such feelings of need, Lamarck did not apply the theory to them, which very much weakened its appeal even to his contemporaries.

Geoffroy Saint-Hilaire, in contrast, proposed that types changed suddenly at the time of reproduction by major jumps in structure, rather than by the re-creation of small changes. The motive force for these abrupt changes was not made clear, nor did the theory help to understand the obviously adaptive nature of the differences between organisms. One of the major arguments for divine creation of species was that organisms seemed designed to fit their environments. An acceptable theory of evolution would need to account for this fit as well as offer a convincing mechanism for the origin of new varieties. When *Origin of Species* appeared, the contradiction between change, as demanded by the evolutionist ideology and the Platonic-Aristotelian ideal of fixed types, had not been satisfactorily resolved.

Darwin's intellectual revolution lay not in his theory that organisms evolved, since that was already widely believed, but in his rejection of Platonic-Aristotelian idealism and his total reorientation of the problematic of evolution. Instead of regarding variation among individuals as ontologically different from the differences among species, Darwin regarded differences within species and differences among species as ontologically related. He took differences among individuals as the primary object of study, concentrating on the real and material differences among the living organisms themselves. He replaced the ideal entities, species, with the material entities, individuals and populations, as the proper objects of study. Darwin's revolutionary insight was that the differences among individuals within a species are converted into the differences among species in space and time. The problematic of evolutionary theory then became—and remains to the present day—to provide the mechanism for this transformation.

The Darwinian Theory

Once it is assumed that evolutionary change is the result of the conversion of variation among individuals into variation among species and of successive alterations of species over time, it is necessary to identify the force for that conversion and to describe the mechanism by which the force converts the variation. That is, we need a dynamics and a kinematics. Darwin supplied both.

The force postulated by Darwin was natural selection, which resulted from the struggle for survival. Darwin dated his concept of natural selection from his reading in 1838 of Malthus's widely known *Essay on the Principle of Population.* Malthus's argument was that human reproduction caused the population to grow geometrically, while the resources available grew only arithmetically, resulting in a struggle among people for resources in short supply. For both Darwin and Alfred Russel Wallace, who simultaneously developed theories of evolution by natural selection, Malthus's human struggle was the model for all species. But the theory of natural selection arose independently from Darwin's study of Malthus, as did the metaphorical term "natural selection." Darwin began *Origin of Species* with the chapter "Variation under Domestication," followed by the parallel "Variation under Nature." "Variation under Domestication" served two functions. First, it illustrated, through examples of pigeons, cattle, and fruit trees, the immense variety of forms that is latent within a species, so that a parallel with the situation in nature could be drawn in the next chapter. Second, it

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