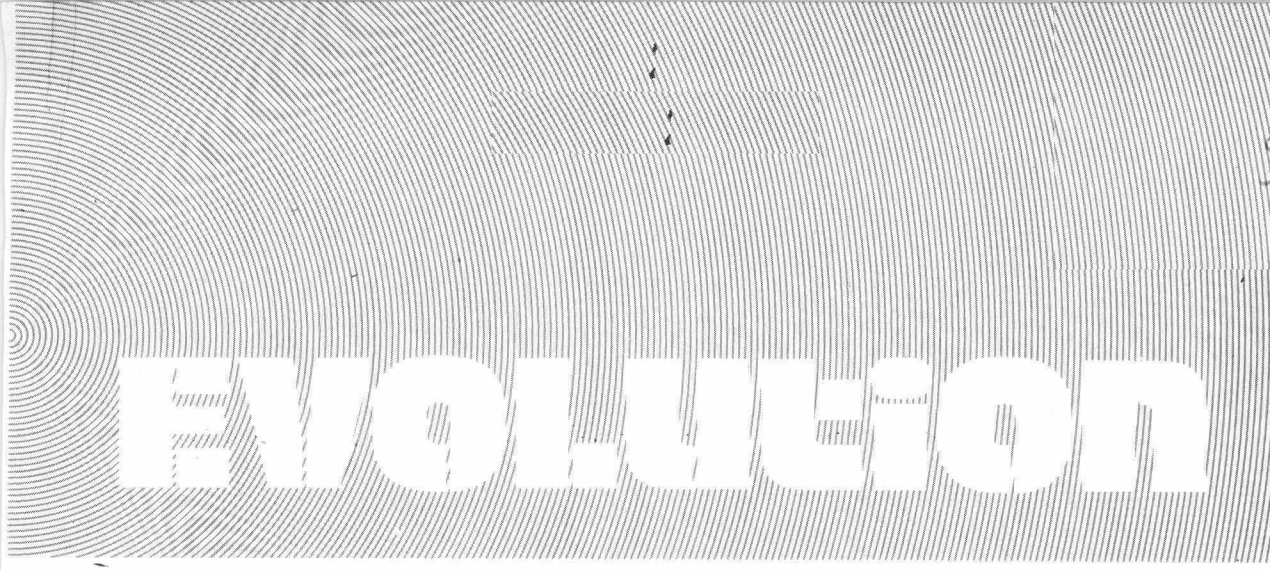
The Science of Evolution

William D. Stansfield



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To my wife, Janis

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Preface

A study of organic evolution is essential for the biologist because only through an understanding of the changes (and the processes which have brought about these changes) in living systems can such disciplines as microbiology, botany, and zoology be integrated into a unified life science. For the nonscientist also, the study of evolution is important for an understanding of the origin of variations and of the development of races, species, and higher taxonomic groups in the biological world. Modern man is naturally inquisitive about his own origin, and the science of evolution is beginning to provide some insights into this subject.

This textbook is written for the undergraduate college or university course in evolution and assumes as minimal preparation at least one introductory course in college biology. The mathematics presented herein can easily be comprehended with the elements of algebra. Some institutions prefer to offer evolution as a freshman level course because of its role in unifying the diverse disciplines of biology. Other institutions prefer the student to become somewhat mature in the biological sciences before attempting a grand synthesis through a study of evolution. In either case, the design of this textbook should prove to be very helpful to the student in an initial study of the subject.

The design of this text is quite different from that of other books on evolution in several respects. Probably the most distinctive features of this text are its attempt to

(1) condense major principles into a form that allows the student to review rapidly the broad sweep of evolution in minimal reading time.
(2) clearly delineate between the presentation of basic concepts and their supporting examples.
(3) present a balance between evidence and processes, as well as between classical theories and mathematical models.
(4) provide thought-provoking questions at the end of each chapter.
(5) prepare the student with the background of facts and theories required for scholarly discussions of evolution.

The text is divided into four major sections. Part I is devoted to a review of some general concepts required as a basis for a detailed study of evolution. This review naturally includes the intellectual legacy left to us by those who have grappled with problems of changes in populations. It also includes a survey of the events that may have been instrumental in the

synthesis of "life" on our planet. However, most of the chapters in this section attempt to answer the question, "What is the evidence that has led biologists to the acceptance of the concept of evolution?"

Part II provides the student with the essentials of heredity in an attempt to answer the question, "What are the origins of genetic diversity in natural populations upon which the evolutionary processes depend?"

Part III establishes a static baseline in the theoretical equilibrium population. Then, one by one, relaxation of the restrictions implicit in such a population is allowed, and their effects in causing genetic changes are defined mathematically. This section attempts to answer the question, "What are the mechanisms that cause evolution to occur?"

Part IV investigates special aspects of the evolutionary process that generate such divergence between populations that they become candidates for different taxonomic status. Some possible origins of man are presented in the concluding chapter. The basic question this section attempts to answer is, "What are the origins of species and higher taxonomic groups?"

This text is most effectively used in a class situation under the guidance of a skilled instructor who can lead discussions of the questions raised in the text or from the students themselves as a by-product of their readings. Much can be learned, however, through an independent study of this text without the benefit of interactions with other scholars. A word of caution: mastery of this subject usually requires that it be thoroughly studied (not merely read). New terminology appears in italics; mastery of terminology is important for efficient communication in discussions of evolution. Exemplary information is set off from the main body of the text so that the reader can clearly differentiate facts, principles, and theory from the examples. A set of objective questions (true-false, multiple choice, and fill-in) and their answers are available for each chapter as a teacher's supplement to this text. The instructor can aid the student in self-evaluation by providing access to the questions in this supplement.

A diligent study of this text may encourage the student to continue scholarship in this field of biology beyond the level presented herein. The brief but comprehensive exposure to the major principles presented in this book should allow the student to read biological journals or advanced treatises concerning evolution with a high level of understanding. The student should be at ease in discussions concerning evolution because of the breadth of subject matter encountered in the study of this text. Finally, by giving serious thought to the discussion questions at the end of each chapter and by prior exposure to the objective questions in the teacher's supplement, the student should be well prepared for classroom examinations.

W. D. S.

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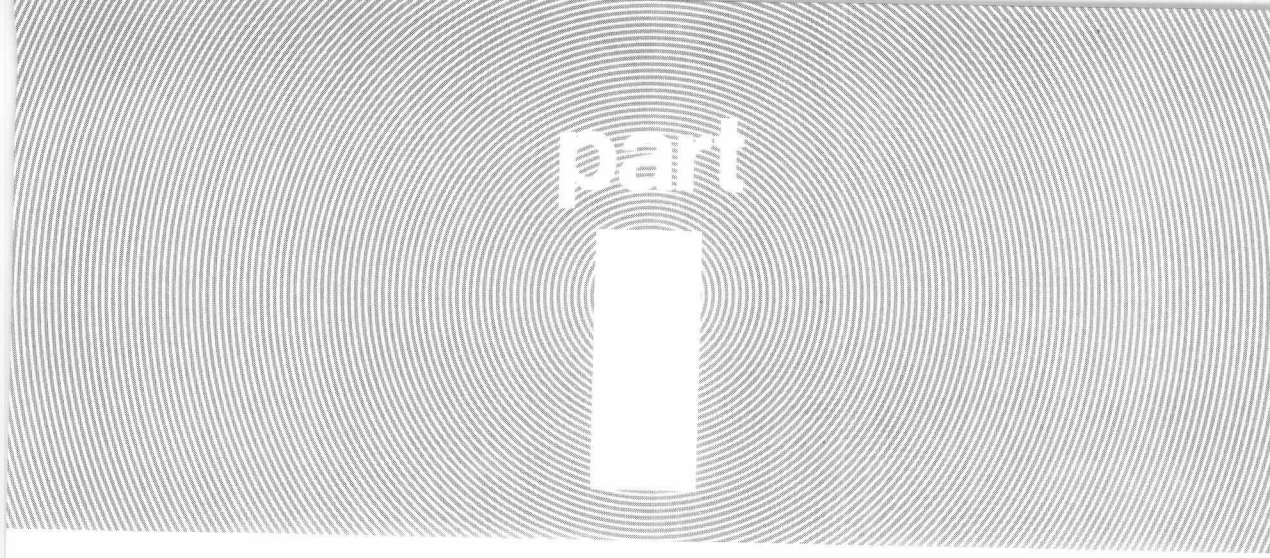

THE FRAMEWORK OF EVOLUTION

INTRODUCTION

It was sweltering that July 20, 1925 on the lawn of the courthouse in Dayton, Tennessee at the climax of the famous "monkey trial." On the stand, as an authority on the Bible and witness for the prosecution, sat William Jennings Bryan (lawyer, lecturer, journalist, editor, Secretary of State, and thrice-defeated candidate for President). Before him stood the attorney for the defense, Clarence Darrow (master jury-pleader and noted agnostic; Figure 1.1). The defendent was a young science teacher in the Dayton High School named John Thomas Scopes (Figure 1.2) who was indicted for teaching evolution. It was really not Scopes that was on trial, but rather the legality of the Tennessee law prohibiting the teaching of evolution in the public schools.

Evolution is a scientific theory proposing that higher forms of life have descended from lower forms by a gradual process of modification through natural mechanisms. This was essentially the thesis of a book entitled *"The Origin of Species"* (1859) by Charles Darwin. In Britain, Darwin's thesis immediately aroused violent opposition from many quarters, especially from the clergy (e.g., Samuel Wilberforce, the Anglican Bishop of Oxford). The impact of Darwin's theory in the United States was delayed by the Civil War. But thereafter, American religious leaders became increasingly disturbed about the concept of evolution. Following the passage of legislation to outlaw liquor after World War I, a religious group

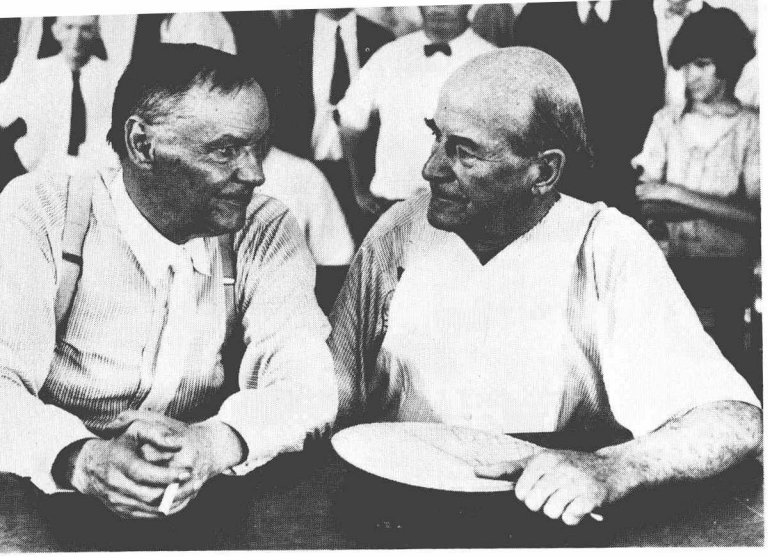

Figure 1.1. Clarence Darrow (left) and William Jennings Bryan at Scopes' trial in July 1925. (Wide World Photos)

called the Fundamentalists began actively lobbying for similar legislation to stifle the "heretical theory of evolution." During the early 1920s several bills prohibiting the teaching of evolution were narrowly defeated in several states. An antievolution bill, introduced by John Washington Butler in the Tennessee legislature, became law in March 1925. Almost immediately, the American Civil Liberties Union prepared to contest the constitutionality of the Butler Act. John Scopes was coaxed by some interested townspeople to be the "guinea pig" in a test case. He agreed to this because of his belief in the theory of evolution, and the fact that he was only 24 years old, unmarried, and could afford to risk losing his job. Furthermore, there were doubts that the law would be enforced or that the penalties, if he lost, would be severe; also the ACLU was picking up the tab.

The trial began on July 10, 1925 with Judge John T. Raulston on the bench. This event attracted nationwide attention as the "monkey trial," because one of the major objections of

Figure 1.2. John Scopes and his father in July 1925. (Wide World Photos)

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the Fundamentalists to the theory of evolution was their notion (not Darwin's) that humans descended from monkeys. Several scientists and Biblical scholars had been assembled by the defense to show that evolution was a scientific fact and that it did not necessarily conflict with a liberal interpretation of the Bible. Judge Raulston, however, ruled that the testimony of such experts was irrelevant to the case. Darrow lost his temper, insulted the Judge, and was promptly cited for contempt of court. The next day Darrow apologized to the court and the trial resumed. Raulston had the court moved to the lawn because of the heat and from fear that the courthouse floor could not bear the weight of spectators and reporters. The trial was not going well for the defense until Darrow decided to fight fire with fire. This was how Bryan, a member of the prosecution team, came to be asked by the defense to take the witness stand as an authority on the Bible. Bryan accepted the challenge. Under a blistering sun, Darrow grilled Bryan for an hour and a half with such questions as, whether he believed that Joshua had lengthened a day by making the sun stand still; . . . that prior to the construction of the tower of Babel, everyone spoke a common language; . . . that the earth was created in seven days of twenty-four hours each. Bryan conceded that the days of creation might have been longer than 24 hours. Under intensive questioning, Bryan confessed ignorance of several subjects on which he had earlier claimed to be an expert. When Darrow inquired of the witness how the Serpent had walked prior to the time that God commanded that it should crawl on its belly and suggested that perhaps it jumped about on its tail, the audience broke into raucous laughter. Bryan then lost his temper, Darrow also became abusive, and a near riot occurred among the spectators; as a result Judge Raulston was forced to adjourn the court. On the following morning, Raulston ruled that Bryan's testimony be stricken from the record.

Darrow broadly hinted in his closing address that he wanted a verdict of guilty so that the case could be appealed to the Supreme Court of Tennessee. Scopes was found guilty and fined $100. In January 1927, the Supreme Court seized on a technicality (the manner in which the fine had been levied) and remanded the case to a lower court with an admonition that the District Attorney not continue the prosecution of "this bizarre case." The D.A. complied, leaving the law intact and Scopes unpunished. Meanwhile Scopes had left teaching to become a graduate student at the University of Chicago; following that he became a geologist with the Gulf Oil Company. Five days after the conclusion of the trial, Bryan died in his sleep. It has been suggested that the strain of the trial had taxed his heart, but it was well known that he was a voracious eater despite a diabetic condition.

Following the initial triumph of the antievolutionists in the Scopes trial, several states initiated bills similar to the Butler Act. However, only one of the twelve bills voted on during 1926 and 1927 passed (this was the one in Mississippi). Despite strong pressure from Fundamentalists, politicians (largely for fear of ridicule) tended to avoid becoming embroiled in legislation that could lead to a similar fiasco. In April 1967, another science teacher in Jacksboro, Tennessee was fired for discussing the theory of evolution with his students. (He was also accused of insubordination, unprofessional conduct, and failing to meet his teaching responsibilities.) Later that same month, the Tennessee State Senate voted to amend the law that led to the Scopes trial forty-two years earlier. According to the amendment, teachers could refer to evolution but only as a theory and must maintain that God's creation is a fact consistent with the "Good Book."

A similar kind of movement also appeared in California during 1969. California is one of the few states that prints its own textbooks for all primary and secondary grades through high school. In November 1969, the California State Board of Education unanimously approved a set of guidelines directing that the creation story should be taught as an alternative to the theory of evolution in science classes. Henceforth, science textbooks in California should also present both concepts. The California Supreme Court decided against this policy in 1972, but compromised by ordering that textbooks should refrain from "scientismic bias" in fostering the notion that evolution is the only possible explanation.

In January 1969, three Roman Catholic nuns (the principal and two teachers) were dismissed from their posts in a Staten Island parochial school for teaching "evolution vs. creation." In January 1970, a bill to repeal Mississippi's ban on teaching evolution was defeated 70 to 42 in the state House of Representatives after an emotion-charged debate. It then had the dubious distinction of being the only state in the nation with laws still discriminating against the theory of evolution.

In August 1975, a U.S. District Court and the Tennessee Supreme Court declared unconstitutional a 1973 law requiring biology textbooks to provide equal space to Biblical and scientific theories. This decision apparently was based on the premise that giving equal space to religious theories in public school texts would violate First Amendment guarantees of separation of church and state. Furthermore, it was beyond the court's comprehension how all the theories or beliefs of every religious sect (from the worshipers of Apollo to the followers of Zoroaster) could be included in any textbook of reasonable size. These objections are all valid, but it appears that the crucial issue (from the standpoint of the scientist) has still been missed; *viz.* the distinction between science and other branches of philosophy (including religion).

Scopes was interviewed in November 1969 shortly after the ruling of the United States Supreme Court on the unconstitutionality of the Rotenberry Act, which forbade teaching the evolution theory in public schools and colleges of Arkansas. Then retired at the age of 68, Scopes told reporters "This country must not rest with the overturning of the 'monkey law,'" warning that "our personal freedom and liberties are never laid to rest because if individuals are not constantly aware of the dangers and pitfalls in the path of maintaining liberties, they become complacent and they'll lose every one of them." He also expressed his dissatisfaction with the educational system, saying "I think that education is for understanding of human emotions and human society, which has not been stressed (in schools) too much. You can learn (in universities) to be the best electrical engineer and still maintain all your prejudices."

Prejudices commonly arise from misunderstandings. There is no room for bigotry in science (although there is ample room for it to occur in other intellectual spheres). Therefore, a major purpose of this text is to delineate clearly the role of science in modern societies apart from other aspects of philosophy. If it is successful in this regard, we can avoid entanglement in useless debates involving religious beliefs and scientific theories. Furthermore, in order to enhance comprehension of Darwin's thesis, the reader should be acquainted with the basic principles of the science of ecology. With the realization that not all readers have backgrounds in philosophy and ecology, this introductory chapter attempts to present enough fundamentals to enable further discussions of evolutionary theory to be more fruitful. Those who are well versed in these subjects may wish to skip the remainder of this chapter.

Science and Philosophy

The 1969 guidelines on science teaching adopted by the California State Board of Education advocated that the words "or designed for" be added after each phrase "is (or are) adapted to" in descriptions of biological attributes in science textbooks. Scientific organizations across the nation, as well as eminent individual scientists (including some Nobel Prize winners) vigorously lobbied to block the passage of such laws. Their objection was uniformly one against mixing science with other forms of philosophy (including religion). The general public is largely unaware of the distinguishing features of science, and until the public becomes educated in this regard, we will never have an end to "monkey wars."

Philosophy encompasses all human thought directed toward a critical evaluation of both sensory input (experience) and extrasensory constructs of the mind (extrasensory perceptions). The term derives from the Greek *philosophia,* which means "love of wisdom." *Science* is a specialized discipline within the realm of philosophy that is bound to a procedural design known as *scientific methodology.* The purpose of science is not to find "facts" or discover "truth," but rather to formulate and use theories in order to solve problems and ultimately to organize, unify, and explain all the material phenomena of the universe. Scientists attempt to avoid the use of "fact," "proof," and "truth," because these words could easily be interpreted to connote absolutes. Nothing in science is deemed absolute. Science deals only with theories or *relative* "truth,"—a temporary correctness so far as can be ascertained by the rational mind at the present time. Science attempts to answer questions such as "Of what structural units are organisms composed?" and "How does an ocean fish function to prevent loss of water?" It is not within the realm of science to find answers to questions such as "What is the purpose of human existence?" and "Why does the universe exist?" These questions are, however, the proper objects of philosophical discourse.

The intellectual approaches used to various degrees by philosophers of all ages include observation, reason, faith, and intuition. Some philosophers favor empirical methodology. *Empiricism* holds that all knowledge comes only from experience. Scientists also use empiricism by relying on sensory observations and experimentation. They use the *inductive method* of reasoning, i.e., the gathering of specific information and postulation of general principles consistent with those specific observations. Scientists realize that their principles (theories) may need to be revised if and when new observations of a phenomenon are found inconsistent with the old general principle under which it would logically fall. Other philosophers, using the *deductive method,* begin with *axioms* (self-evident general principles accepted without proof) and use reason to derive specific conclusions based on those axioms. Obviously, the conclusions of deductive reasoning can be no sounder than the axioms that serve as a starting point. Thus, deductive reasoning proceeds from the general phenomenon to the specific, whereas inductive reasoning proceeds from the individual case to the universal. Both instances require a degree of faith (reliance) in the ability of the methodology to provide answers to our questions. Some philosophers claim that certain things can be known directly without reasoning or sensual verification. This is *intuition,* an inexplicable type of personal revelation forbidden to the scientist as an explanatory method.

All scientific methodology has, at its core, the observation of phenomena in the natural world. The initial steps in the science of biology were taken when direct observation of organisms was substituted for philosophical speculations based on intuition and/or deductive reasoning. Describing and classifying organisms is a pioneering step in any biological discipline. Scientists always attempt to be as objective as possible in their observations, although it is too much to expect human beings to be entirely free of unsuspected biases. Furthermore, to have scientific validity the observations must be capable of verification by others using the same observational techniques, i.e., they must stand the test of repeatability. This is why it is important that all steps in a research project be carefully documented in publications for consumption by the scientific community. Many biologists are still involved in this most basic task of making descriptive observations, especially for taxonomic groups with very large numbers of species such as protozoans (single-celled animals), nematodes (roundworms), and insects.

Experimental science, as distinguished from purely descriptive science, also begins with observations. These experiences provoke questions that define a problem area. Questions amenable to scientific investigation must be both relevant and testable. For example, the question "Does God exist?" is scientifically irrelevant because it does not pertain to the material world and because it is not subject to an experimental test in which He is present in one situation and absent in another. The next step is the formulation of a hypothesis, i.e., an educated guess as to a possible answer to the problem. The hypothesis may be stated as an either-or alternative—for example, "The oxygen liberated by photosynthesizing plants is derived either from water or from carbon dioxide." An experiment is then designed, with appropriate controls, to provide the evidence by which the validity of the hypothesis can be evaluated. The results of the experiment are then analyzed in an attempt to reach a decision. It is often impossible to answer scientific questions with a simple yes-or-no conclusion. Much experimental work in biology is quantitative and requires statistical treatment by which it may be possible to conclude, with a certain degree of confidence, that the hypothesis under test is consistent with the data (or unacceptable, as the case may be). If the original hypothesis is invalidated, new hypotheses may be generated and subjected to redesigned experimentation and analysis in a search for an acceptable explanation. Once an answer to a specific problem is available, it may be possible to postulate the ramifications of the verified hypothesis to a broader base of application. Thus emerges a scientific theory that serves as a catalyst for further specific investigations to test its general validity. A good theory has predictive value. A few scientific theories have such a high degree of predictive value that they are called *natural laws*. This is why science has proved to be so useful in both its pure and applied aspects. Most scientific theories, however, are ephemeral. Exceptions will likely be found that invalidate a theory in one or more of its tenets. These can then stimulate a new round of research leading either to a more comprehensive theory or perhaps to a more restrictive (i.e., more precisely defined) theory. Nothing is ever completely finished in science; the search for better theories is endless.

The interpretation of a scientific experiment should not be extended beyond the limits of the available data. In the building of theories, however, scientists propose general principles by extrapolation beyond available data. When former theories have been shown to be inadequate, scientists should be prepared to relinquish the old and embrace the new in their

never-ending search for better solutions. It is unscientific, therefore, to claim to have "proof of the truth" when all that scientific methodology can provide is evidence in support of a theory.

> For example, the assertion that populations of organisms can change in their genetic composition from one generation to another (i.e., evolve) is undisputed, even by the creationists. To say without qualification that "all present life has evolved from more primitive forms" is unscientific because such a statement is an absolute. A scientifically acceptable restatement is that "scientists have found a great deal of evidence from many sources which they have interpreted to be consistent with the theory that all present life has evolved from more primitive forms."

As scientists, humans are bound not only to scientific methodology, but also to a set of premises accepted on faith. This probably comes as a shock to many people who thought that they knew what science was all about. Scientists believe that every phenomenon results from a discoverable cause. They assume that the behavior of the universe is not capricious, but describable in terms of constant laws, such that when two sets of conditions are the same, the same consequences may be expected. Scientists believe that the forces now operating in the world are those that have always operated (*uniformitarianism*), and that the universe is the result of their continuous operation. They think of the world and the phenomena in it as consisting of sets of relationships rather than absolutes. They do not regard generalizations as final, but are willing to modify them if they are contradicted by new evidence. Scientists must rely on material and mechanical explanations of phenomena rather than on nonmaterial or supernatural factors. They often think in terms of continua, distrust sharp boundary lines, and expect to find related classes of natural phenomena grading imperceptibly into one another. They expect nature to be dynamic rather than static and to show variation and change. They expect that in any situation involving competition among units of varying potentialities, those that work best under existing circumstances will tend to survive and be perpetuated. Scientists prefer simple and widely applicable explanations of phenomena. They attempt to reduce their view of the world to as simple terms as possible. They attempt to incorporate all phenomena into a single consistent natural scheme, but recognize that contradictory generalizations may be necessary to describe different aspects of certain things as they appear to us (e.g., the corpuscular vs. the wave theories of light). These are the boundaries and guidelines within which science is conducted. Scientists must attempt to explain phenomena *mechanistically,* i.e., in terms of the laws of chemistry and physics. They should not resort to *vitalism,* the assumption that material phenomena are controlled by supernatural powers. They also should not resort to *teleology,* the notion of purpose in natural events. Rather, their thinking must be *causalistic,* that events occur only as previous events permit them to occur. In scientific reasoning, scientists are careful to avoid *anthropocentric* explanations, which attribute human-like qualities to other species.

> The statement "Ground squirrels store nuts in their burrows in order that they will have something to eat during the winter when food is scarce" is both anthropocentric and teleological because it ascribes a human-like mind to the animal, allowing it to think and plan ahead for a winter it may not yet have experienced and to take appropriate action for a specific purpose in the future. A scientifically acceptable restatement is that "ground squirrels appear to be stimulated by a shortened length of daylight to store nuts in their burrows; this food helps sustain the animals through the winter."

Scientific explanations of natural events are inherently without absolute truth, without innate value, and devoid of purpose (nonteleological). This is the framework within which science operates. It is really because of these restrictions that science has been so productive in problem solving.

Now we return to the philosophers. They too seek answers to questions, but their questions may range far beyond the realm of science. *Philosophy* is concerned with the rules and methods of correct thinking (*logic*); with the origins, nature, and limitations of knowledge (*epistemology*); with the understanding of reality other than through sense perceptions (*metaphysics*); and with the study of values (*axiology*). Philosophy is involved in science, religion, government, education, personal assessment, and indeed in every aspect of human endeavor.

The scope and methodologies of philosophy are so different from those of science that arguments derived along philosophical lines of reasoning often cannot be accepted by the scientist; likewise, conclusions derived through scientific methodology are not always acceptable to the philosopher (depending on the basic premises of his or her particular beliefs). *Creationists* are vitalistic philosophers who believe that all "kinds" of life were created *de novo* by a supernatural power (God) and that these life forms have not changed substantially since their advent. They acknowledge that fossils are the remains of prehistoric life forms, but do not accept the theory that some of them were ancestral to quite different forms living today. The creationist view may well be absolute truth, but this is not within the realm of science to determine. The evolutionist is a scientist who works within the confines of scientific methodology, trying to explain mechanistically how populations of organisms change today and then, by extrapolation of these processes back through time, to explain the origin of species and other taxonomic categories in a coherent theory of evolution. Both the creationist and the evolutionist have faith in their respective methodologies to provide answers to questions. However, the creationist can easily explain any phenomenon by simply saying "God did it." This approach, though it may be perfectly correct in an absolute sense, does not foster further inquiry and is therefore intellectually emasculated. The scientist has no ready answer for most questions and must labor for solutions, and must continually monitor theories for their congruity with objective data.

A law that would require inclusion of the creationist view in science textbooks might only serve to confuse the reader, unless a lengthy explanation of the kind we have just been through is presented at the outset. Such a book might more properly be termed a philosophy text rather than a science text.

Whereas science is "godless," the people we call scientists need not be! When attempting to answer questions outside the realm of science, the scientist must become a philosopher. Therefore, it is philosophically permissible for a scientist to believe in God or not, as he or she finds the rationale to make the choice. Those who claim that a person cannot believe in God and practice science obviously do not understand the complementary nature of these two major realms of human thought. Perhaps many scientists actually believe that a supernatural "Force/Being" is maintaining the natural laws of the universe according to His purposes, but vitalism and teleology should be avoided in their scientific explanations.

When we come to the origin(s) of life, both creationists and evolutionists are forced into the role of speculators. Laboratory experiments conducted with presumed primitive earth

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