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THE SIGNIFICANCE OF THE DATA OF SYSTEMATICS AND PALEONTOLOGY FOR THE EVOLUTION-CREATIONISM CONTROVERSY

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Creationism is an attempt to explain the findings of science within a literal interpretation of the Bible. As such, creationism rejects the conclusions of systematics and paleontology that life has had a long history of descent with modification (evolution). This paper critically examines the arguments of creationists, focusing on seven fundamental problems within the systematic and paleontological literature and creationists' writings about them. 1) The taxonomic units of creationism are claimed to be the "created kinds" of the Bible. The concept of "created kinds" has never been defined operationally, and consequently creationists have never been able to delineate the boundaries of these "kinds" or provide a list of them. Hence, creationism provides no basis at all for empirical investigation of biological diversity. 2) Creationists can claim only that "created kinds" arose by fiat, supernatural creation, which is a religious belief not open to scientific investigation. 3) Creationists' arguments that similarities among the kinds of organisms can be ascribed to similar functional purposes is overwhelmingly rejected by empirical science. 4) Creationism must predict (by its internal logic) that similarities among taxa will be nonhierarchical, but this prediction has been known to be false even long before evolution was accepted (that is, nature is decidedly hierarchical). 5) Creationism cannot explain the highly nonrandom biogeographic patterns of organisms except by ad hoc religious arguments. In particular, creationists invoke the Noachian deluge as explaining why organisms must have dispersed over the globe from Mount Ararat. This is religious apologetics, not science. 6) Creationists attempt to explain the stratigraphic distribution of fossils in terms of a Noachian deluge. Such a catastrophic flood could not have produced the nonrandom regularities observed in the fossil record. 7) Creationists' denial of transitional forms in the fossil record is totally without scientific merit. Many taxa known from the fossil record are intermediate morphologically between earlier and later forms, and some of these intermediates can be postulated to be ancestral to other taxa. Creationists have never addressed the problem of transitional forms with scientific data of their own.

The data of systematics and paleontology overwhelmingly reject creationists' interpretations. Life has had a long evolutionary history and there was no universal flood.

Belief in the Bible as an historically factual, inerrant account of the universe, earth, and life has been present within portions of Judeo-Christian thought for centuries. Consequently, the rise of Biblical literalism in modern society has historical continuity extending back more than 2000 years. Today's

Biblical literalism, also called creationism, advances few, if any, new arguments, but merely recasts in contemporary language what are taken to be timeless, indelible truths. Prior to the early to mid-nineteenth century, creationism was a generally acceptable framework for interpreting the findings of nature. Yet by that time many branches of knowledge had already rejected Biblical literalism as being of much help in explaining natural phenomena--but the one area of study still captured by creationist thinking was biology. The great question of biology--how do we explain the diversity and complexity of life?--was of particular importance because of its obvious implications for the meaning of human existence. With the rise of systematic and comparative biology, including paleontology, increased numbers of biologists began to realize that the empirical record provided by their science was incompatible with Biblical literalism, and this schism has widened more and more since that time. Today, creationism can only be viewed as anachronistic within the framework of contemporary science. If such is the case, why would so many scientists spend an inordinate amount of time dealing with this issue? The answer, I think, is that although creationism is a mere annoyance as far as the intellectual challenge it presents to scientific knowledge, it is a manifestation of a moderately successful political and economic force in this country--what has been termed the New Right. Although I do not believe that the majority of political conservatives necessarily embrace extreme Biblical literalism, the creationists themselves have exploited this conservative environment to the hilt, and in so doing have turned science into a political exercise rather than the pursuit of knowledge. Professional creationists, or their followers, have been directly responsible for textbook censorship throughout this country, the educational effects of which will be felt for years. Creationists, through their lectures, debates, and writings, have tried their case before the public rather than within the scientific community itself. Finally, they have attempted to use our judicial system to force their religious beliefs into the public school curriculum. Thus, creationists contribute to the public's wariness of science by picturing scientists as biased, closed-minded persecutors of Biblical truth. Some creationists, including Henry Morris, Director of the Institute for Creation Research, have even gone so far as to suggest a causal link between a belief in evolution and atheism, communism, racism, and fascism (9, 10, 16). All of these activities are designed to erode public confidence in science, science-teaching, and our educational system in general. It must be kept in mind that creationists are attacking not only biology (and especially evolution) but all branches of knowledge, from history, philosophy, and sociology to physics, chemistry, anthropology, and geology. Their professed goal is to rewrite all knowledge to conform to their own literal interpretation of the Bible.

The short-term success of creationism has been due not to the merits of its arguments but to the effectiveness of its political strategy. Creationism is a good example of the triumph of style over substance. In the long run, however, creationism is failing because the alternatives it presents to contemporary scientific and theological thinking are vacuous. Within evolutionary biology, the discoveries of systematics and paleontology first convinced many biologists that the diversity of life could not be explained by the creation scenario of Genesis but rather had to be related to a long history of continuous change. And because the scientific content of systematics and paleontology played such a pivotal role in the development of evolutionary thinking over the last century, these disciplines have been the obvious target of much creationist literature. Several well-known books--in particular, The Genesis Flood (16), Scientific Creationism (11), Fossils in Focus (1), and Evolution: The Fossils Say No! (8)--have presented creationist interpretations of systematic and paleontological data.

In this paper I want to examine creationist thinking about the findings of systematics and paleontology and contrast that with contemporary scientific viewpoints (see also 2). This comparison will be organized around seven major themes or predictions derived from the proposition that the history of life resulted from a long evolutionary process on the one hand, and from the belief that present life was created ex nihilo, on the other. The statements of creationists regarding these predictions are taken primarily from the four texts just cited, not only because these are among the most authoritative of the creationists' writings but also because they represent current creationist opinion on the subject. For those readers seeking up-to-date refutations of creationism, particularly from a paleontological and systematic perspective, the recently published books by Eldredge (6) and Newell (13) are highly recommended.

SYSTEMATICS AND PALEONTOLOGY

Systematics is that branch of biology concerned with discovering order in nature's taxonomic diversity and structural complexity (for modern summaries of systematics see 7, 12, 17). Systematics as a scientific discipline antedated the rise of evolutionary thinking and, as creationists like to point out, early systematists--the most famous being Linnaeus--were creationist in their outlook. Few of them, however, thought very deeply about the general significance of their findings, preferring instead merely to catalog nature as evidence of "God's divine creation." Of course, if we are honest, we must admit that many present-day systematists also do not think much about the implications of their work, and prefer instead to accept, rather uncritically, their findings as evidence of evolution. The moral, then, is not that science is any less susceptible to a priori assumptions than is creationism. It is, indeed, that we must have these assumptions if we are to interpret the data of science at all. The solution to this apparent dilemma is quite simple: The assumptions themselves must be scrutinized when we examine the empirical structure of nature. As I will discuss below, the assumptions of evolution and creationism imply very different predictions about the way nature is structured. However, in science no a priori assumption is immune to criticism and possible rejection, whereas in creationism all these assumptions are taken as religious truths, immune to rejection.

The discipline of systematics has undergone major theoretical and methodological changes over the last 10 to 15 years. Consequently, the literature exhibits much controversy, argumentation, and differences of opinion, exactly what we would expect in a vigorous and exciting scientific discipline. Creationists have exploited this ferment by selectively choosing quotations and scientific opinions that on first appearance seem to support some of their claims. I will negate this ploy by freely acknowledging the diversity of opinion within systematics and paleontology, and at the same time assert that this diversity is irrelevant for comparing the predictions of evolution with those of creationism.

Another problem that needs brief discussion concerns the methods of paleontology. As we shall see, the theory and methodology of systematics bear directly on the interpretation of fossil material and on the opinions of paleontologists regarding the implications of the fossil record for evolution. Once again, creationists have exploited this scientific debate by deliberate misquotation, distortion of the factual evidence, and by ignoring evidence contrary to their position, methods that conventional science views as being unscientific, unscholarly, and unethical.

PREDICTIONS OF EVOLUTIONARY THEORY AND CREATIONISM

This section discusses five systematic and two paleontological predictions of evolutionary theory and of creationism. Each prediction, or theme, will be described and then evaluated in terms of the available scientific evidence. Alternative theories or worldviews should entail different explanations or interpretations of the patterns we see in nature. Evolution and creationism are two radically different worldviews, and they make predictions that are diametrically in conflict with one another. But in order to evaluate these alternatives properly, some basic principles--the criteria of science--must be applicable to both. The most important criterion of any scientific explanation is that it be susceptible to empirical investigation. If creationism is scientific as the creationists contend, then their predictions and explanations must be capable of empirical investigation. A second criterion, accepted by all science, is that explanations must be naturalistic, that is, they cannot invoke magic, revealed truth, or supernatural causation. Actually, both these criteria are intimately related in that they simply require that before a statement can fall within the domain of science, it must have some affinity to the real world as defined by our senses. These basic criteria of science are accepted by virtually all practicing scientists and philosophers of science.

BASIC TAXONOMIC UNITS

Perhaps the most important task of systematics throughout its history as a science has been to describe and classify the different "kinds" of organisms. This endeavor has proceeded for several thousand years, but the rules were codified by Linnaeus only in the eighteenth century. All scientific theories about the structure of nature must make reference to one or more real entities. Within systematics, we can term these entities basic taxonomic units.

The fact that taxonomic units were being identified before the acceptance of evolution demonstrates that their delimitation can be independent of contemporary views about their origins. Pre-Darwinian systematists, like their modern counterparts, clustered individual organisms into groups, each of which could be recognized by some defining characters. Moreover, some pre-Darwinians, for example the great French naturalist George Leclerc Comte de Buffon, were sufficiently sophisticated to use reproductive cohesion as one of the criteria for delimiting taxa: those individuals freely interbreeding with one another must be of the same kind; those incapable of interbreeding are somewhat different. Using morphological and reproductive criteria, experienced, pre-Darwinian systematists and their modern counterparts almost certainly would reach similar conclusions about the taxonomic composition of a given sample. A point worth stressing is that this approach to delimiting taxonomic units is primarily empirical, with relatively few conceptual overtones.

Within modern evolutionary biology, the taxonomic units are called species, and species identifications are determined mainly by morphological distinctness and, to a lesser extent, by reproductive cohesion, much as systematists have been doing for over 200 years. For the most part, therefore, species can be defined nonarbitrarily--the kinds of organisms are discrete. Naturally, there is a small proportion of the known plants and animals whose taxonomic status is uncertain. Either these taxa are poorly differentiated from others, that is, they have few well-marked defining characters, or as is more often the case, they simply have not been studied sufficiently to permit a proper judgment at

this time. Many evolutionists have noted that if evolution is true, if there is descent with modification, then we would predict there to be a small percentage of plants and animals that have not yet changed very much in comparison to their close relatives. What we see in nature, therefore, is compatible with an evolutionary worldview.

But what about a creationist world view? Ironically, modern creationists have departed from the empiricism of pre-Darwinian creationists and instead have adopted an entirely religious, metaphysical view of taxonomic units. Whereas the pre-Darwinians chose to investigate the natural world from an empirical, scientific viewpoint (even though they still saw the world in religious terms), contemporary creationists have retreated intellectually by abandoning that scientific approach for one of revealed truth.

The creationists call their taxonomic units "created kinds." Defined the way it is, a "created kind" is decidedly nonarbitrary: a "created kind" is a group of plants or animals that had a separate, supernatural creation. The notion of a "created kind" obviously is a religious concept and not scientific (Whitcomb and Morris [16, p. 2] referred to them as "divinely-established lines of demarcation"), and few creationists hide that fact. In science, the derivation of a definition is relatively unimportant, but how that definition is used is crucial. Science thus asks the question, if an entity is defined in a particular way, will that permit us to investigate nature effectively? If not, then the definition is of little use. Judged in these terms, is the "created kind" a useful scientific concept? The answer is decidedly no.

In the first place, the creationists themselves cannot define "created kind" in such a way that it can be employed empirically. Obviously the Bible does not list the different "created kinds" nor does it specify how they might be recognized. This has led to immense difficulty for the creationists, so much so that even the leading creationist spokesmen are exceedingly confused as to exactly what a "created kind" might be. Consider, for example, the following discussion of Duane Gish (8, pp. 34-37) in his book, Evolution: The Fossils Say No!

> A basic animal or plant kind would include all animals or plants which were truly derived from a single stock. In present-day terms it would be said that they have shared a common gene pool. All humans, for example, are within a single basic kind, Homo sapiens. In this case, the basic kind is a single species. (8, p. 34)

This definition is revealing. It seems to suggest that reproductive cohesion is the most important criterion defining the boundaries of "created kinds," and indeed other creationists have adopted a similar point of view (16; 18, p. 58). Moreover, in this quotation Gish seems to admit that species have some objective reality. Gish begins to get himself in difficulty, however, the more he discusses the problem of "created kinds." Consider his further comments:

> . . .in other cases, the basic kind may be at the genus level. . . . We cannot always be sure, however, what constitutes a separate kind. The division into kinds is easier the more divergence observed. . . . Among the vertebrates, the fishes, amphibians, reptiles, birds, and mammals are obviously different basic kinds. . . . Within the mammalian class, duckbilled platypuses, opposums, bats, hedgehogs, rats, rabbits, dogs, cats, lemurs, monkeys, apes, and men are easily assignable to different basic kinds. Among the apes, the gibbons, orangutans, chimpanzees, and

gorillas, would each be included in a different basic kind. (8, pp. 34-37 [italics added])

The perceptive observer will realize that Gish has placed himself squarely opposite that of a Biblical interpretation of "created kinds." If, however, Gish does support a Biblical belief in "created kinds," then he has instead committed a grievous error in logic. In either event, the only certain conclusion is that Gish does not understand what a "created kind" is, which for a creationist would seem to be a real problem.

Remember that creationists believe each "created kind" was created separately from every other. Thus, when we diagram the logical structure of Gish's discussion, we see that it is in conflict with the notion of a separate creation, for Gish's "created kinds" are hierarchically arranged: mammals are vertebrates, apes are mammals, gibbons are apes, and so on (Fig. 1). Logically, gibbons and apes cannot be separate "created kinds" and still be members of the mammals, which Gish also identifies as a "created kind." Independently "created kinds" cannot be hierarchically arranged, one within the other! So it does appear that Gish has some difficulty with the concept of "created kinds," but no more so than do other contemporary creationists.

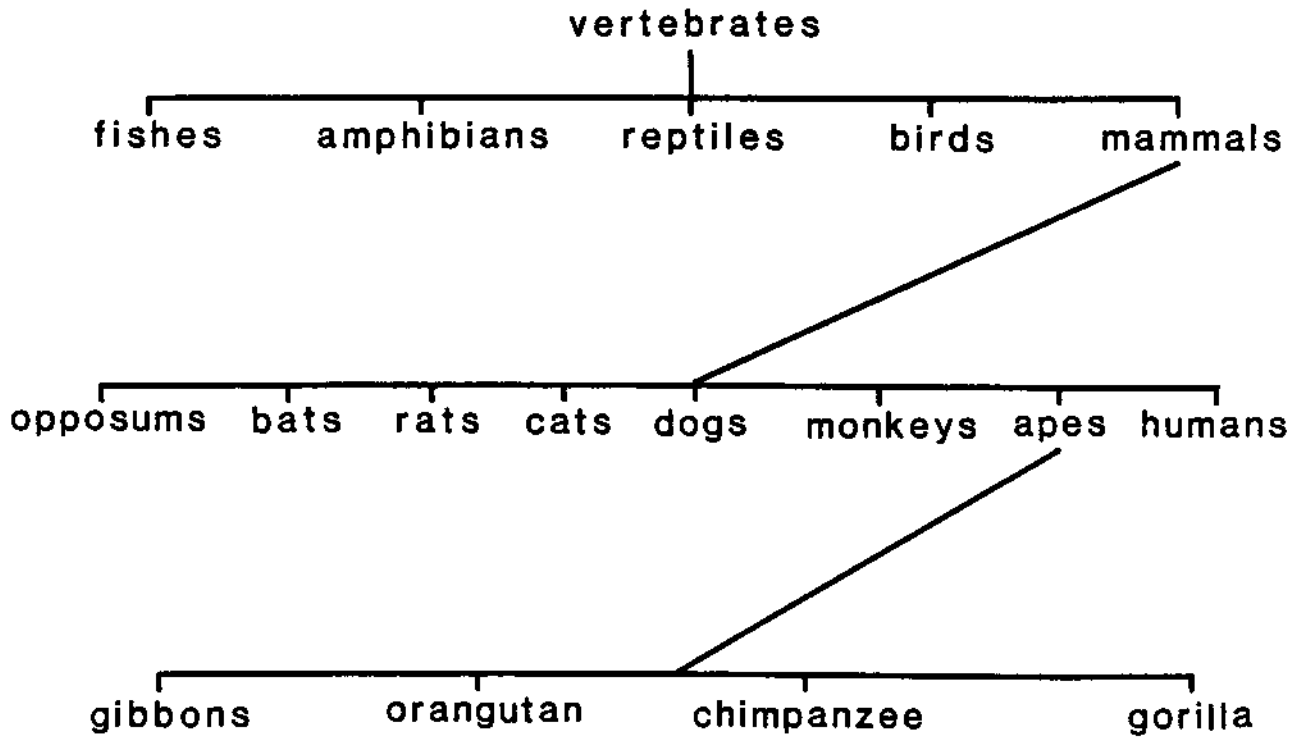

Figure 1. The logical structure of Duane Gish's (8, pp. 34-37) discussion of "created kinds." Gish apparently seems to admit to a hierarchical structure of nature (i.e., mammals are vertebrates, apes are mammals, gibbons are apes), but calls all of these groups "created kinds." Under the tenets of creationism, however, "created kinds" are separately created entities, thus it is logically not possible for one "created kind" to be a member of another "created kind." One conclusion is that Gish does not understand what a "created kind" is. See text.

Why, we might ask, have creationists abandoned the pre-Darwinian concept of taxonomic units in favor of a metaphysical viewpoint of "created kinds"? Creationists never have discussed this in their writings, and for good reason. If modern creationists adopted that earlier view of kinds, then they would have to admit that species arise through naturalistic processes. As noted earlier, pre-Darwinian concepts of species are not that much different from modern views, but modern biology has now established beyond doubt that populations which become geographically isolated can differentiate morphologically and genetically. Even the creationists concede this. Under the pre-Darwinian view of species, these differentiated populations would be classified as new species--and this would be evolution, much as Darwin conceived of it! Therefore, contemporary creationists have chosen to play a word game--they simply claim that these different species are not really different but constitute a single "created kind." Viola!--no more evolution. This is just one example of how creationists are less interested in understanding nature than they are in forcing the observations of nature to conform to their religious prejudices. Rather than practice science, creationists simply call the evolution of new species "microevolution" and claim that this is change within a "created kind." According to them, change from one "kind" to another would be macroevolution, which they say does not occur. This argument is not only inane but tautological since they cannot show that "created kinds" have any objective existence.

MODES OF ORIGIN OF TAXA

There is little to discuss here. Evolutionists propose that the origin of species can be explained by naturalistic processes, and there is a large scientific literature confirming this. When populations become isolated by a geographic or climatic barrier, they sometimes will differentiate, forming a new species. Within some plants, and a few animals, individuals sometimes will spontaneously double their chromosome number thereby making it impossible for their offspring to interbreed with other individuals of the population having the normal chromosome number. This process, called polyploidy, has been thoroughly documented, both in nature and in the laboratory, and is in direct contradiction to the claims of the creationists that we cannot observe the origin of new species.

Whereas evolutionists present a scientific explanation for the origin of species, creationists can only rely on revelation to explain the origin of "created kinds." Their argument is as follows: the Bible is factually inerrant and it says God created the different kinds of organisms. So be it. Clearly, creationists defend their views only on the basis of religious truth, not scientific evidence.

HOW DO WE EXPLAIN SIMILARITIES?

One of the great observations of nature, known since the time of Aristotle if not before, is that the different kinds of organisms share similarities with one another. Evolutionists and creationists have different explanations why organisms should be similar in one or more characteristics. Perhaps Darwin's greatest contribution was to propose that similarity was due to inheritance from a common ancestor. To be sure, some similarities can be ascribed to an independent acquisition, presumably because of design for analogous ways of life (called convergent evolution), whereas others are due to chance resemblance and

are of no biological significance. Nevertheless, the majority of observed similarities are easily interpretable as inherited characters. All mammals, for example, share hair because that character was inherited from the mammalian common ancestor, not because hair is a character needed for a specific way of life that is shared by all species of mammals (which hair manifestly is not).

Creationists, on the other hand, view similarities in one of two ways: either they are shared because all members of the same "created kind" possess that character, or because the similarities were supernaturally given to different "created kinds" in order to perform a specific role in a similar type of environment. As the creationists themselves state:

> Creationists. . .interpret the same similarities as evidence of common creative planning and design. . . . Creationists explain them [i.e., similarities] as structures designed by the Creator for specific purposes, so that when similar purposes were involved, similar structures were created. (11, pp. 69-70)

This statement, based as it is on a literal interpretation of the Bible, was published in a book designed for the science classroom of the public school system. It is clearly a religious statement, and not open to scientific investigation. Nevertheless, certain of their claims can be examined. For example, according to creationism, all similarities shared by organisms of different "created kinds" must be ascribed to similar functional purposes. This prediction has been falsified time and again by biologists. Take a simple example. All tetrapods--including amphibians, reptiles, birds, and mammals--possess in their forelimbs a humerus, ulna, radius, and other assorted bones of variable number. Why do all these animals have a humerus, ulna, and radius located in the same relative positions? The evolutionist would say this is an example of inheritance from a common ancestor. The creationist cannot account for this similarity. Surely, they cannot claim that all these kinds of animals represent a single "created kind"; and surely they cannot claim that these groups use the forelimbs in similar ways (this is demonstrably false, of course). In fact, there are many such examples of similarities being used for very different functions, and all these would contradict the creationists' prediction. But there is an even stronger argument against creationists' interpretation of similarity, which we can now consider.

IS NATURE HIERARCHICAL?

Evolution is descent with modification, and this implies a prediction: similarities will be hierarchically distributed among organisms. If an ancestral species is subdivided by an isolating barrier, the characters of the descendent populations evolve at different rates. Some characters remain unchanged; some become modified to one degree or another. This explains why all species possess both primitive characters (those remaining unchanged) and derived characters (those having been modified). Homo sapiens, for example, retains primitive vertebrate characters such as a vertebral column, but also has derived characters such as an enlarged brain. Descendants inherit derived characters and thus similarities are hierarchically shared (Fig. 2A).

If the creationist worldview were correct, then we would predict the absence of a hierarchical pattern of shared similarities. The creationist position is that the different "created kinds" were created separately from one another:

similarities should not be shared between "created kinds" unless, supposedly, those similarities are concerned with analogous functional requirements. Obviously, this cannot produce a hierarchical pattern, except perhaps by change (Fig. 2B).

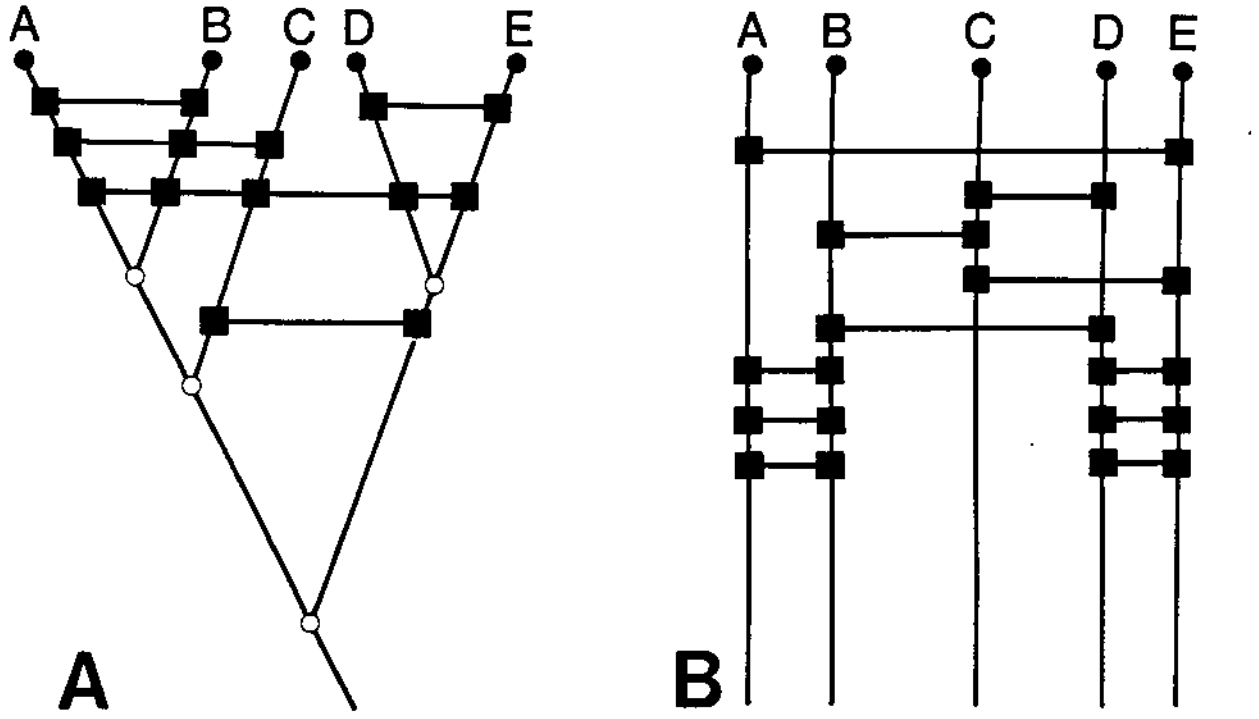

Figure 2. (A) The evolutionary hypothesis predicts that the majority of similarities will be arranged hierarchically among species (A-E), with a few exhibiting a pattern of convergence. (B) The creationist scenario predicts that similarities will not be hierarchical but instead will be shared between "created kinds" according to their functional similarity. (See text.)

The data of comparative biology are unequivocal on this point: similarities among organisms are arranged hierarchically. This pattern was not discovered by biologists with an evolutionary bias, moreover, but was also recognized by many pre-Darwinian creationists (12). Only after the introduction of evolution was this hierarchy interpreted as descent with modification. Pre-Darwinians could only explain this hierarchical structure as the divine plan of God, but such an explanation is easily recognized to be nonscientific: what we see is what God did.

BIOGEOGRAPHICAL PATTERNS

All biologists truly concerned with understanding the history of life have recognized the importance of patterns of distribution. One hundred years before Darwin, the French naturalist Buffon noted:

> And when, because of revolutions on the globe or by the force of humans, animals are forced to abandon their native country--when they have been hunted or relegated to distant climes--their nature has undergone alterations so large and so profound, that it is not recog-

> nizable at first glance; to recognize it requires the most attentive inspection, experiment, and analogy. (1766: 316; cited in 12, p. 362)

What Buffon recognized, over two hundred years ago, is that evolutionary change is very much a geographic phenomenon. It is thus no coincidence that Darwin (5) devoted two chapters in The Origin to biogeography. Moreover, the recognition of the importance of biogeography has continued unabated to the present day. And for good reason. The distribution of organisms makes sense only in the light of evolution. Is it any wonder, then, that creationists have been reasonably silent on this subject?

Perhaps few disciplines bring into focus the vacuous nature of creationist thinking as much as biogeography; it epitomizes the superficiality in their methods of investigating biological problems and lays bare their true religious motives, thereby making a mockery of their claims to scientific objectivity. The observations of biogeography provide a clear-cut test for the predictions of creationism and evolution.

Let us first consider the predictions about distribution patterns that follow logically from the creationist scenario. Most creationists believe that all the kinds of organisms were created approximately 10,000 years ago, although some would claim possibly as much as 20,000 years ago. Then, about 5000 years ago there came the Noachian deluge, covering all the surface of the earth, destroying all organisms except those that could exist in an aqueous environment and those that found safe haven on the boat said to have been built by Noah. The organisms came to Noah, and once the deluge was spent, all the presently known animals and plants dispersed from the boat, located on Mount Ararat, to the far corners of the globe, where they are now distributed. Lest this summary of creationist thinking be thought of as a caricature of their writings, consider the following quotations from the most authoritative source in the creationist literature, The Genesis Flood (16, p. 86):

> The more we study the fascinating story of animal distribution around the earth, the more convinced we have become that this vast river of variegated life forms, moving ever outward from the Asiatic mainland [i.e., from Mount Ararat], across the continents and seas, has not been a chance and haphazard phenomenon. Instead, we see the hand of God guiding and directing these creatures. . .in order that the great commission to the postdiluvian animal kingdom might be carried out, and "that they may breed abundantly in the earth, and be fruitful, and multiply upon the earth" (Gen. 8: 17).

The animals found their way to Noah and survived on the boat because of "the possible impartation of migratory instincts and powers of hibernation to the animals by God with respect to the gathering and caring for the animals during that year of cosmic crisis" (16, p. 87).

Whitcomb and Morris (16, p. 87) note that "it is by no means unreasonable to assume that all land animals in the world today have descended from those which were in the Ark." Moreover, "population pressures, search for new homes, and especially the impelling force of God's command to the animal kingdom (Gen. 8: 17) soon filled every part of the habitable earth with birds, beasts, and creeping things."

These statements of Whitcomb and Morris are blatant religious apologetics

rather than science. The problem of plant and animal distribution is so vexing for creationists that they are presented with only two choices: either ignore the subject altogether or appeal to revelation as a method of explanation. Be that as it may, what biogeographic patterns would be predicted from the creationist scenario if supernaturalistic influences were excluded?

First, because the scenario is based on dispersal from a center at Mount Ararat and takes place within a period of time not exceeding much more than 5000 years, we would predict the absence of strong patterns of endemism (i.e., localized distributions) and a very high percentage of widespread species. Dispersal promotes cosmopolitanism; a short time scale would not allow significant differentiation and the consequent endemism.

Second, because dispersal is known to be highly random in its occurrence, we would predict the absence of common general patterns of organism distribution. In other words, it would not be possible to reconstruct a historical pattern of animal distribution. The creationist scenario, in fact, predicts that animal distributions should be chaotic and highly random.

Third, because the creationist time scale is so abbreviated--less than 5000 years--we certainly would predict the absence of any congruence between the historical patterns of biotic distribution and those of earth history.

These are some of the main predictions of creationist biogeography. How do they compare with analogous predictions of evolutionary biogeography? In assessing these predictions, note that evolutionary biogeography does not assume a short time scale, but instead claims that the history of life is older by many orders of magnitude. Moreover, present day biotic distributions are not assumed to be the result of dispersal alone, or that dispersal was from a single center located in or near eastern Turkey. Some predictions of evolutionary biogeography would be as follows:

First, because of long periods of time, species ranges will show a cycle of fragmentation, followed by range expansion, to be followed again by fragmentation. Many of these fragmented, localized populations will differentiate into new species. Accordingly, evolutionary biogeography predicts that narrow endemism will be very frequent and cosmopolitanism relatively infrequent.

Second, because biotas are being fragmented by rather long-term geologic and climatic events, biogeographic patterns--that is, the distribution patterns displayed by groups of species postulated to have descended from a common ancestor--will be decidedly nonrandom. The components of a biota will exhibit congruence in their histories, and dispersal phenomena will be seen to contribute noise to any analysis of the biota.

And finally, because evolutionary biogeography readily accepts a long time scale, a third prediction is that the historical patterns of biotic distribution will exhibit considerable congruence with the patterns of earth history.

We can now ask which set of predictions is confirmed by the geographic data available to science. The answer is that the predictions of evolutionary biogeography are strongly supported by scientific data and those of the creationists are resoundingly rejected. Without question the vast majority of organisms are narrowly endemic, with only a small minority exhibiting cosmopolitanism or widespread distributions. Our familiarity with widespread species creates an

intuitive bias. They seem to be relatively common, but such species actually are quite rare. If these distributions were the result of a very recent dispersal from Mount Ararat, just the opposite would be expected, that is, cosmopolitanism would be the rule, not the exception.

The second prediction of evolutionary biogeography also is met. Distribution patterns are decidedly nonrandom. For example, modern biogeographers have shown that taxa living on the southern continents have highly congruent patterns of relationships from one group to the next. Many taxa in tropical South America have as their close relatives taxa living in Africa, whereas cool-temperate groups often have their relatives in Australia or New Zealand. These relationships would be totally unexpected if the creationist scenario were true.

And, as should be obvious from the preceding example, biogeographic patterns exhibit a strong correlation with earth history. In the Southern Hemisphere, for example, the breakup of the Gondwanaland continents has had profound influences on the biogeographic history of plants and animals (Fig. 3). Such a correlation would be inconceivable within the creationist time scale. Creationists have been notably unsuccessful in dealing with continental drift, the evidence for which is overwhelming. Creationists lamely try to suggest that

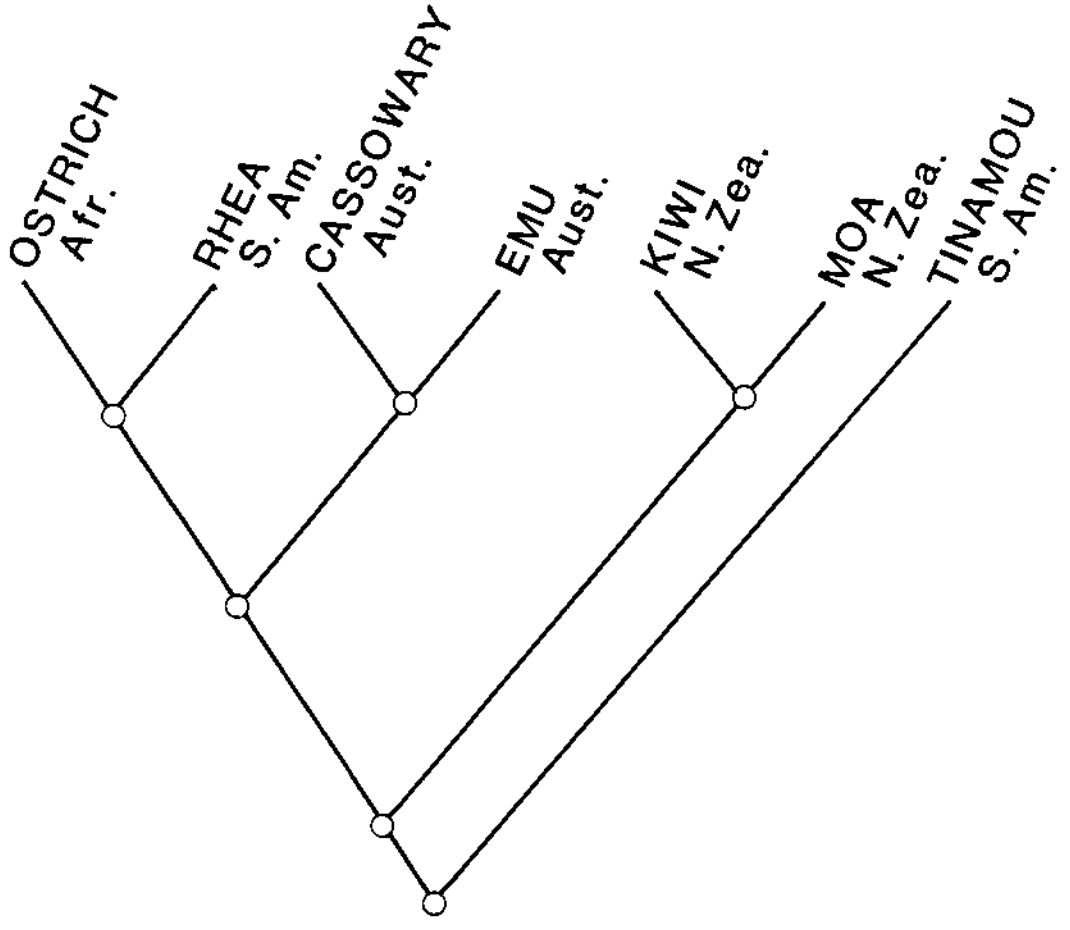

Figure 3. A phylogenetic hypothesis for the flightless ratite birds and the flying tinamous (3). Note their distributions on the widely separated southern continents. The simplest scientific explanation is that their common ancestor was distributed on a united Gondwanaland continent and that they evolved in isolation following continental breakup and drift.

drift was somehow the result of the Biblical flood, but one might think that even they would see the absurdity of their position. Continental drift has been shown to have had a profound effect on organism evolution and distribution (4).

THE STRATIGRAPHIC DISTRIBUTION OF FOSSIL ORGANISMS

The creationist scenario and the hypothesis that life has had an evolutionary history imply two unequivocally distinct predictions regarding the distribution of fossil organisms in the stratigraphic record. Creationists view the geological strata, particularly the fossiliferous sedimentary portions, to have formed from a very recent, catastrophic deposition provoked by the Noachian deluge. According to this story, all the created organisms were placed in their respective locations by God. Then, along comes a tremendous aqueous cataclysm, descended from the heavens and upwelled from the deep, which sweeps them up and sends them plunging into a giant, global, Noachian bouillabaisse. Now, given the nature of a violent flood capable of pulverizing thousands of feet of bedrock and then transporting it for long distances while spreading it over the surface of the earth, one might logically expect that the components of this soup would exhibit a considerable degree of commingling. In other words, the only reasonable prediction is that the fossil record should look like scrambled eggs--ma-rine organisms mixed with terrestrial, fresh water with marine, advanced verte-brates with primitive invertebrates, and so on. This is what logic would dictate --and down-to-earth empiricism too, for on very small scales, floods clearly produce a near-random sorting of objects, not a nice orderly sequence. Do the creationists accept this logic? Of course not, for they know that to do so would make their position look foolish. Instead, they clumsily interpret the empirical record of fossil distributions within the framework of their Biblical story. The crassest example, perhaps, can be found in the Institute for Creation Research book, Scientific Creationism (11). Rather than expect a good deal of com-motion from a flood of the magnitude they propose, the outcome is one of sublime order: marine invertebrates would be on the bottom, these would be followed by marine vertebrates, then amphibians and reptiles, and finally birds and mammals. We are even told (11, p. 119) that humans would have escaped burial and floated on the top, which would be a neat trick given a vicious universal flood.

Creationist writings make a mockery of the labors of thousands of geologists and paleontologists, who have struggled for more than 200 years to reconstruct the history of the earth and life. Indeed, many of the scientists who discovered this evidence were creationists themselves and did not even consider the idea of evolution when they mapped out the stratigraphic distribution of fossils. They found that the fossil record is decidedly nonrandom. Our conceptions of the phylogenetic relationships of organisms, that is, the phylogenetic connections from primitive to more advanced species, are very highly correlated with the age of the sediments displayed in the geological column. However, it cannot be stressed too strongly that, contrary to creationists' claims, our determination of the age of the stratigraphic column is independent of the phylogenetic sequence of the organisms housed in those rocks: the fossils need not be used to date the strata, and the column itself cannot be used to determine the relationships of the organisms.

The geological column displays the general phylogenetic trends of the history of life. Creationists explain that trend differently; it results, they say, from the different habitats occupied at the time of the flood--those organ-

ism in the same habitats were preserved together. But such an explanation cannot account for the orderly preservation we see from one taxonomic group to another, i.e., from "lower" to "higher" forms. The deluge scenario gives every reason to expect wholesale intermixing of the fossil taxa throughout the flood waters, but that simply does not occur. The creationist prediction is unequivocally rejected by paleontology. There was no universal flood.

TRANSITIONAL FORMS

Perhaps no claim of the creationists is made more loudly and with such undeniable conviction than the fossil record is lacking in transitional forms between major groups of organisms. Furthermore, the creationists assert, the gaps we see in the fossil record are incompatible with the assumption of evolution but fully expected under that of creation. These two statements abound in the creationist literature and are an integral part of their catechism.

One can certainly agree with the creationists as to the conflicting predictions arising from the evolutionary hypothesis and the creationist scenario. If evolution has occurred, then certainly transitional forms should be present; if all the kinds of organisms were created de novo, then logically, transitional forms would be absent.

As is well known, evolutionists claim to have identified transitional forms in the fossil record. Creationists, on the other hand, simply deny their existence. How can this conflict be resolved? At the outset, the question of transitional forms is primarily an issue of systematic analysis. Most paleontologists have recognized this to one degree or another, whereas creationists have been less interested in the scientific investigation of the problem than they have in manipulating the data to support their theological worldview. The identification of transitional forms is a systematic issue because it entails the comparative analysis of morphological data, the interpretation of genealogical relationships among all the taxa involved, and a comparison of these results with detailed stratigraphic information. One of the factors contributing to the controversy within contemporary paleontology over the identification of transitional forms has been the historical predisposition of paleontologists to lend more weight to the stratigraphic sequences of their fossils than to their comparative systematics. Thus, some paleontologists have used stratigraphic position as an important criterion for identifying ancestral taxa. Part of the confusion apparent in the scientific literature and the religious writings of the creationists, I suggest, stems from the definition of "transitional form." Is a taxon a transitional form only if it can be assumed to be directly ancestral to another taxon? Or is it transitional if it is "intermediate" in morphology but not necessarily directly ancestral? Some paleontologists, but all creationists, have not appreciated the distinction.

Consider, for example, the two phylogenetic hypotheses depicted in Fig. 4. In Fig. 4A, species Y is postulated to be the direct ancestor of species Z. Species Y and Z are postulated to be related to one another because they share a unique character, b', not shared with species X. With respect to characters c and d, species Y has the primitive condition relative to species Z, which has characters c' and d'. Species Y not only is intermediate morphologically, it also is postulated to be ancestral. In Fig. 4B, on the other hand, species Y has a unique character, c', and cannot therefore be postulated as the direct ancestor of species Z, which lacks that character. Nevertheless, species Y is

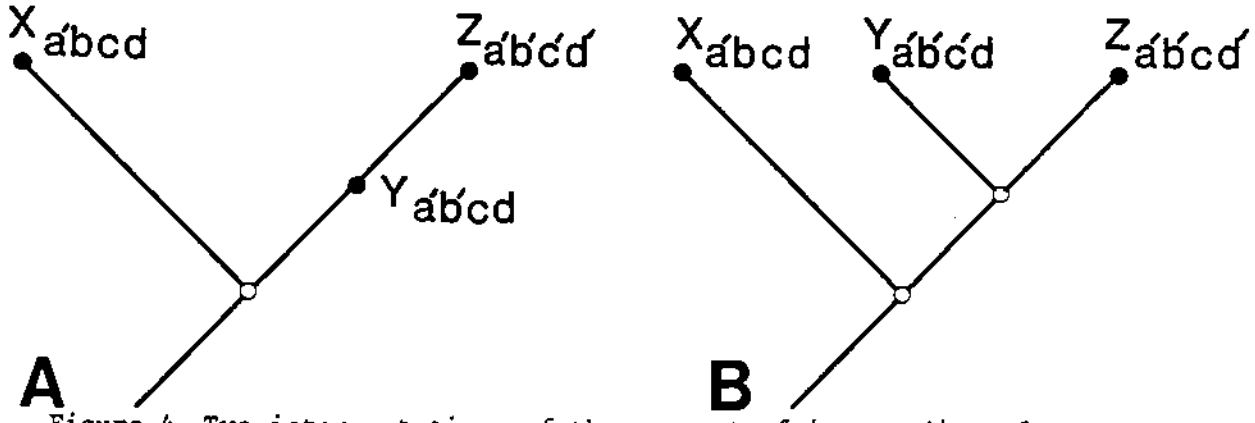

Figure 4. Two interpretations of the concept of intermediate forms. In both hypotheses, each species (X, Y, Z) has four characters, each of which can be expressed as a primitive character-state (a, b, c, d) or derived character-state (a', b', c', d'). In 4A, species Y is postulated to be an intermediate form that is a direct ancestor of species Z, whereas in 4B, species Y is an intermediate form that shares a common ancestry with species Z. In either case, species Y is "intermediate" or "transitional" between species X and Z. (See text.)

still morphologically intermediate in that it is more advanced than species X but less so than species Z. In a real sense of the word, species Y is a transitional form in both of these examples because it has the primitive characters of its ancestors and shares derived characters with its descendants or close relatives.

Both kinds of hypotheses have been documented in the fossil record, although a moment's reflection should make one realize that identifying a direct ancestor in the fossil record is extremely difficult. First, that ancestor must have been fossilized and then discovered by a paleontologist, both very unlikely events. And second, the fossil material itself must be of sufficient quality in order to analyze its morphology properly, another unlikely situation. Nevertheless, paleontologists have discovered fossil species that are good candidates for a direct ancestry of other groups.

Much more common, of course, are examples conforming to the situation diagrammed in Fig. 4B. One of the most famous cases is the intermediate taxon, Archaeopteryx lithographica, which is morphologically transitional between theropod dinosaurs and modern birds (14). Thus, Archaeopteryx has numerous primitive characters found in theropods and a few advanced characters, such as feathers and a fused furcula (or wishbone), shared with birds. In this sense, then, it is a true transitional form between some reptiles and birds, although most paleontologists would not necessarily declare it to be the direct ancestor of birds.

The important point, of course, is that the creationist notion of "created kinds," with its implied absence of evolutionary relationships among species, unequivocally predicts the absence of transitional forms. With respect to the empirical record available to science, the results of paleontology and systematics have falsified that prediction unambiguously.

Creationists have attempted to argue their case, not on the merits of the scientific data, but by deliberate distortion of the scientific literature.

Without undertaking the detailed morphological comparisons that are necessary to evaluate ancestor-descendent hypotheses, creationists dogmatically assert that these transitional forms do not exist, that there are gaps in the fossil record. From this they make the disingenuous conclusion that the fossil record supports creation and not evolution. If evolution were true, they imply, there could not be gaps in the fossil record. Now either the creationists are deliberately distorting science in an attempt to persuade a public not familiar with scientific arguments, or they are simply ignorant of the findings of modern paleontology. For over a hundred years paleontologists have recognized the large number of gaps in the fossil record. Creationists make it seem like gaps are a deep, dark secret of paleontology, when just the opposite is the case. I have already noted one of the reasons for gaps--the low probability of species being fossilized and then discovered. Correlated with this is the growing realization that most species probably arise very rapidly geologically speaking; morphology sometimes does not take as much time to transform as paleontologists once thought. Therefore, if morphological transformations take place over short periods of time (in a geological sense), then the probability of preserving that time interval in the sedimentary record is greatly diminished.

In summary, creationists have characterized the evolutionary process as being slow, gradual, and uniform, whereas virtually all modern evolutionary biologists recognize the fact that rates of evolution can be highly variable. Some evolutionary events are apparently extremely rapid so that frequent gaps in the fossil record are to be expected. Nevertheless, numerous examples of morphologically intermediate taxa--transitional forms--have been described from the fossil record, and that record indisputably falsifies the creationist view of the history of life.

CONCLUSION

I have argued that the predictions of evolutionary comparative biology (systematics) and paleontology are upheld by the empirical findings of science. In contrast, not a shred of scientific evidence supports the claims of creationism, namely that entities called "created kinds" exist, that they have arisen de novo, that nature is not organized hierarchically, that the taxonomic hierarchy is randomly distributed through the fossil record, and that there are no transitional forms between the major groups of organisms. All these claims are simply false and derive from Biblical literalism, not the findings of science.

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