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Systematics, Comparative Biology, and the Case against Creationism

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Systematics is the study of organic diversity through space and time. The emphasis of systematics is on the theory and methodology that is applied to the historical analysis of diversity rather than on the atemporal aspects of diversity that more properly might belong to the field of ecology.

Viewed in this way, systematics investigates problems of species, primarily the ways in which they are thought to originate, their genealogical relationships with other species, and the historical aspects of their distribution in space and time. To investigate these questions systematists use the methods of comparative biology, including biogeography. Systematics plays a central role in modern evolutionary biology and contributed significantly—in the guise of comparative anatomy and biogeography—to the formulation of Darwin's (1859) ideas on evolution. Conceptually, however, the field of systematics has made signifi-

cant, if not revolutionary, advances over the last two decades, and it is becoming increasingly apparent that systematics is the area of biology that defines the *pattern* of organic change through space and time and, consequently, specifies that body of knowledge that theories of evolutionary *process* must be capable of explaining. Systematics, therefore, provides an important focus for many of the recent controversies arising from the creationist challenges to evolutionary biology.

Evolutionary Species versus "Created Kinds"

The notion that we can categorize, or classify, organisms into groups on the basis of shared similarity is ancient indeed. So too is the realization that there exist groups of individual organisms that are defined in terms of their ability to interbreed with one another and thereby produce like kinds, but that at the same time lack the ability to interbreed freely with other such groups (although accidental interbreeding might be observed sometimes). These interbreeding groups are the entities biologists call species, and the concept of reproductive cohesion has been used historically as a criterion for defining their unity or individuality, regardless of whether the investigator believed in a supernatural creation of species or in their evolutionary origin.

Accompanying the reproductive criterion has been the recognition that organisms show variability not only within species but among them as well. In fact, morphological discontinuity among clusters of like individual organisms has been the single most important basis for recognizing species limits, especially because information about interbreeding is known for only a very small percentage of the species currently recognized.

For a long time, biologists have known that morphological variation within a reproductively defined species is often greater than that existing between two *sympatric* (i.e., living in the same area) species that are virtually identical morphologically but that are themselves reproductively isolated. In cases such as this, the phenotypes of the two sympatric species usually exhibit slight differences in morphological or behavioral characteristics that have a significant influence on their reproductive isolation (see Mayr 1963, chapters 3-5). The point to be made here is that the presence of reproductive isolation is not necessarily related to the degree of phenotypic difference, and at least in sympatric taxa it is

their reproductive discontinuity that is of significance when naming them as distinct species.

When distinct but obviously similar forms occur in different geographic areas (a distribution pattern termed *allopatric*), it is not possible to apply a criterion of interbreeding. Traditionally, systematists have relied on the degree of difference of these isolates, as compared to the differences shown by sympatric pairs that are close relatives, to establish whether they are separate species or whether they are best treated as subspecies (geographic races) of a single species. In these cases the most important observation of scientific interest is the existence of differentiated taxonomic units; whether these units are treated as species or subspecies is less important.

For over one hundred years, biologists have expended intense effort in describing the different kinds of organisms, in discovering how their phenotypic variation is expressed geographically, and in investigating their reproductive relationships to similar taxa. This vast biological literature represents a substantial body of knowledge on the subject, and thus the superficial and illiterate treatments of this knowledge in the creationist literature calls into question the creationists' claim of scientific objectivity and competence. Creationist views of the importance and recognition of the "kinds" of organisms derive solely from a literal acceptance of the Bible rather than from the application of a scientific methodology to data on variation, distribution, interbreeding, and ecology. Consequently, it should come as no surprise that creationists ignore most of the conventional procedures of systematics. The depth of their scientific acumen is illustrated by a particularly elementary example: they seldom even refer to taxa by their scientific names, preferring instead to adopt scientifically imprecise names such as dog, cat, bat, horse, and so on. To creationists, the species of modern biology should be replaced by the "created" or "basic" kind:

A basic animal or plant kind would include all animals or plants which were truly derived [presumably by special creation] 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. . . . In other cases, the basic kind may be at the genus level.

[Gish, 1979, p. 34]

A vague notion of genetic compatibility seems common to most creationists' concept of kinds:

The oft-repeated statement, however, that God's creatures brought forth progeny 'after their kind' would strongly indicate that plants and animals which can interbreed and produce offspring would be the same 'kind.' A corollary conclusion would then be that production of offspring from matings between two different kinds would be impossible. [Siegler 1978, p. 37]

In this quote Siegler seemingly identifies fertile offspring as the criterion for defining kinds, but on the same page he contradicts this and restricts "kinds" to those organisms that can effect fertilization, regardless of whether the zygote remains viable. He calls these kinds "baramins" (from the Hebrew *bara*, created, and *min*, kind, after Marsh 1947), and notes that they may apply to any portion of the conventional taxonomic hierarchy. Thus, *Homo sapiens* is a baramin at the species level, and at the upper extreme Siegler suggests the entire family of waterfowl (Anatidae) is a baramin or single "created kind."

Siegler's apparent confusion over just how a "created kind" should be recognized (fully viable offspring or merely ability to fertilize) is paralleled in other creationist writings:

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, opossums, 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. [Gish 1979, pp. 36-37]

This is a very revealing passage, one that would seem to raise a serious problem for the creationists and especially for Gish. If we accept for the moment the creationist position—that the various basic kinds were created *de novo* apart from one another and that basic kinds can generally be recognized by some criterion of interfertility (e.g., Gish 1979, p. 36)—then one must conclude that Gish, a leading creationist, does

not understand what a "created kind" really is. This conclusion follows logically from his own statement: an organism cannot be a "created kind" in and of itself (the gibbon, the orangutan, the chimpanzee, and the gorilla in the above quote) and at the same time be an element of another, more inclusive "created kind" (e.g., "apes," or mammals). Given the notion of "created kinds" accepted by most creationists (Whitcomb and Morris 1961, pp. 66-67; Morris 1974, p. 180; Wysong 1976, p. 58), Gish's position is logically indefensible. Moreover, one could scarcely maintain "fishes," mammals, bats, and so forth as single "created kinds" on the basis of *any* criterion of fertility. If, on the other hand, Gish wishes to maintain the accuracy of his statement, then the concept of "created kind" becomes vacuous: essentially, it is anything a creationist says it is. Naturally, most creationists probably would not want to adopt this position, and thus we might expect most creationists would disagree with Gish's interpretation of "created kinds." It is curious, therefore, that none of them have sought to challenge Gish's interpretation and to discuss the question of "created kinds" in a critical manner. Then again, because the concept of "created kinds" is a manifestation of a fundamentalist religious belief rather than of a scientific attempt to understand nature, why should we expect the creationists to adopt a critical attitude?

If the concept of "created kinds" seems inapplicable because of creationists' inability to clearly express what it means, the lack of any rigorous methodology for investigating these supposed entities underscores the weaknesses in their entire approach to science: they misunderstand or distort modern thinking within evolutionary biology and, once the latter is summarily rejected, replace it with a naively conceived substitution. Let's examine a case history.

Lammerts (1970) studied specimens of the Galapagos (or Darwin's) finches in the collections of the California Academy of Sciences. He compared coloration among the species and measured body (something a professional ornithologist would never do because of effects of preservation) and bill size. He then observed that "if one were to remove all the species labels and arrange the Darwin's finches from the largest to the smallest in body and bill size, complete intergradation would be found" (1970, pp. 360-61), and he goes on to argue that all these species are based merely on minute differences in size and shape and that, in reality, they should constitute only a single species, in this case probably

one "created kind." Lammerts's conclusion has been cited by other creationists (e.g., Gish 1979, p. 36) as an example of how the species of evolutionary biology can be translated into "created kinds."

In his zeal to demonstrate how biologists have misunderstood the species limits within Darwin's finches, Lammerts exemplifies the creationists' inability to deal critically with scientific data without distorting it for their own ends. He conveniently does not mention that many of these species occur sympatrically with each other on one or more islands and fail to interbreed: they are reproductively discontinuous. Lack (1947), who is cited by Lammerts, makes specific note that hybridization among the species of Darwin's finches is rare, if it is present at all.

By all criteria that creationists themselves recommend, each species of Darwin's finch would have to be called a "created kind." This leads one to wonder why they would adopt the position that there is only one species of finch, based as it is on blatantly inaccurate biological information. I can suggest a number of obvious reasons, none of which creationists are very candid about in print:

1. Creationists would be uncomfortable if they had to admit that the species concept of evolutionary biologists, based as it frequently is on morphological criteria, actually does mirror the existence of reproductively discontinuous units. In so doing they would have to accept the reality of many more "created kinds" than they would prefer (one of their reasons for minimizing the number of kinds is so that they will all fit on the Ark!).

2. Creationists would then have to admit that species—reproductively distinct kinds—can evolve by isolation and subsequent differentiation. Creationists readily admit to evolutionary change *within* reproductively distinct "created kinds," but they deny the origin of these kinds from one another.

Unfortunately for them, creationists have used the Darwin's finches as an example of evolutionary change within what they assumed to be a single "created kind" (Lammerts 1970, p. 361; Gish 1979, p. 36). But by their own definition, these finches cannot represent a single "created kind"—each species is reproductively isolated. It follows, therefore, that creationists have essentially admitted—through their own error of not understanding the biological data—that new species can arise by isolation and subsequent differentiation. The only logical escape for the creationists would be to admit openly that they cannot define "created

kinds" and cannot provide a methodology to identify them. But they do not dare do this, for it would repudiate their claims that "creationism" can be studied scientifically (see below).

3. Generally speaking, creationists are uncomfortable if their "created kinds" are not markedly distinct morphologically. The more similar their "created kinds" are to one another, the more difficult it is to deny the reality of evolution. It should be apparent that small changes accumulated during speciation, as in the Darwin's finches, when extrapolated through geological time provide a plausible basis for apparent large scale differences among groups of organisms. It is no doubt apparent to the creationists as well—hence their reluctance to conceive of "created kinds" narrowly.

4. If creationists admitted that small-scale changes can occur *between species* by evolutionary means as in the Darwin's finches—and I have argued that creationists effectively do this—then they would have problems in explaining the marked differences among the differentiated populations of humans. If new species of finches can originate by naturalistic processes, why not *Homo sapiens*? And the differences between *Homo sapiens* and some fossil hominoids are uncomfortably small in comparison to the variation among present-day human populations.

In summary, the concept of "created kinds" is essential to the acceptance of creationism. The "created kind" is the unit of a creation event just as the species is the unit of evolutionary change. Consequently, if the concept of "created kind" cannot be defined so that it can be used to interpret and investigate nature, then it is of little or no importance for the growth of knowledge. If it is not important for the growth of knowledge, creationists cannot maintain the charade that "creationism" provides a basis for the scientific investigation of nature. I have argued in this section that the creationist concept of "created kind" cannot be defined objectively without leading to the conclusion that one "created kind" can give rise to another by naturalistic means, which is nothing more than evolution as has been defined for centuries. Indeed, I have argued that creationists, in their confusion, have admitted to the evolution of "created kinds." They will, of course, vehemently deny this and will tenaciously cling to the concept of "created kinds," for it is, after all, only an article of religious faith, and of a narrow fundamentalism at that.

Biological Comparison: A Natural Hierarchy or Analogical Similarity?

Human beings communicate with language, and language is a classification system, with words generally signifying group membership of objects or concepts. The basis of any classification system is similarity. Long before the concept of evolution was accepted by the biological community, natural historians were making classifications of organisms and were attempting to identify those groups that could be called "natural" (for a recent history of these attempts, see Nelson and Platnick 1981). In preevolutionary times "natural" usually was interpreted to mean those groups assumed to be the product of a "creation event" and that evidenced a "divine plan." After the rise of an evolutionary viewpoint, natural groups were those thought to have descended from a common ancestor. In both cases some aspect of similarity was used to define the content of these natural groups.

For several centuries now, countless biologists have been discovering new forms of life—both living and fossil—and as a result of extensive comparison of their intrinsic attributes (morphological, physiological, biochemical, and behavioral), they have come to the realization that nature is hierarchical. This means that the groups of organisms (taxa) themselves can be arranged hierarchically on the basis of a repeatable, and therefore nonrandom, internested set of similarities. Consider the simple example of figure 1 (modified from Eldredge and Cracraft 1980, p. 25). If we make comparisons between the five organisms of figure 1, we find that they exhibit similarities in characters of embryonic and adult morphology and that these similarities can be used to construct a hierarchical arrangement of the organisms. This hierarchical arrangement of similarity is called a *cladogram* and is usually expressed as a branching diagram (fig. 1d), but it can also be expressed as a classification, much like the conventional Linnaean classification scheme used throughout biology (fig. 1e). A cladogram can be viewed as a scientific hypothesis, because it is a statement about the general pattern of similarity to be observed among these five groups. There is a prediction that further similarities will be congruent with the hierarchical arrangement of the cladogram (see Eldredge and Cracraft 1980; Nelson and Platnick 1981; and Wiley 1981, for modern treatments of this material). And a prediction of this kind can be tested empirically.

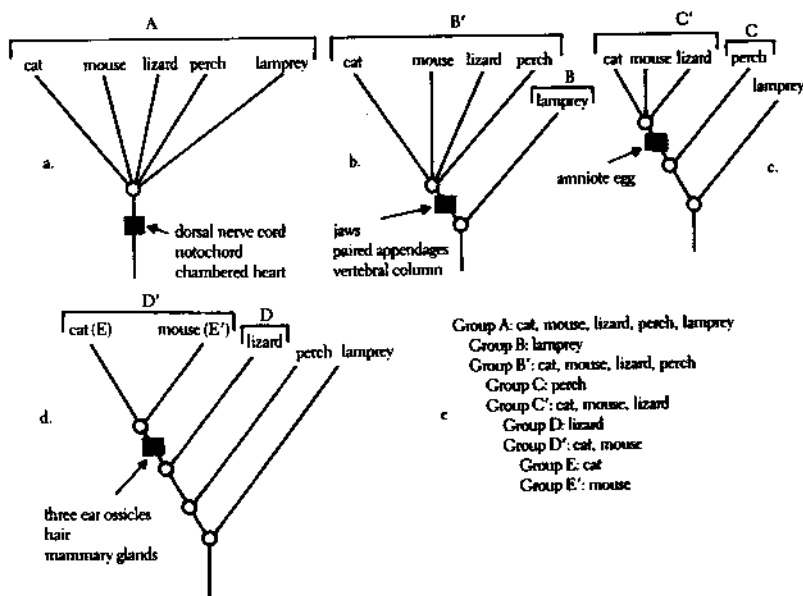


Figure 1. SIMILARITIES (CHARACTERS) AMONG ORGANISMS ARE SHARED IN A PATTERN THAT IS HIERARCHICAL IN STRUCTURE

These shared similarities, interpretable by biologists as evolutionary novelties (black squares of the figure), can be used to cluster the five organisms into groups and subgroups whose similarity relationships can be expressed either as branching diagrams (a-d) or as a classification (e).

In the past, branching diagrams of this sort have often been taken to express the pattern of general overall similarity, but a German entomologist named Willi Hennig showed that this was not the case. Hennig (1966) noted that similarities are of two basic kinds, nonhomologous (convergent) and homologous, and that the latter may be either primitive or derived. Hennig's chief insight was to demonstrate that branching diagrams should be based on derived similarity alone and that primitive and nonhomologous similarities cannot lead to the discovery of a natural hierarchy.

In evolutionary terms, derived similarities (or characters) are seen to be evolutionary novelties—for example, the feathers of birds or the hair of mammals. Both these characters are interpreted by biologists to be derivative of scales, such as those found in reptiles, and although feathers

and hair can be used to define the two groups mentioned, *within* birds and mammals, feathers and hair are each seen to be primitive and thus cannot unite subgroups of birds or mammals.

To most comparative biologists, the concept of primitive and derived characters has evolutionary connotations, but it need not be interpreted in this way only.

Just as a broad comparison of adult morphologies can lead to a hypothesis about a primitive to derived sequence (scale to feathers, for example), which then can be employed to construct a hierarchy of groups within groups, so too can embryological differentiation lead to a hypothesis concerning whether characters are more general or widespread (e.g., generalized vertebrate egg) or whether they are less general or restricted in their distribution (amniote egg). Thus, embryological transformations can yield hypotheses about taxic hierarchies—they have been used for that purpose since the last century—without demanding an assumption of evolution (this is not to say, however, that an evolutionary interpretation cannot be applied).

The literature on the methodology of comparative biology (systematics) is large and relates in detail how comparative data can be used to construct branching diagrams; three recent summaries of these methods are Eldredge and Cracraft (1980), Nelson and Platnick (1981), and Wiley (1981). The remainder of this section will discuss how creationists have viewed the problem of similarity and, most importantly, will argue that the *hierarchical pattern* produced by the shared similarities observed among organisms is predicted by a hypothesis of evolutionary descent with modification but *not* by an assumption of special creation.

One explicit assumption of a creationist world view is that all the different "kinds" of organisms originated more or less at once, without any temporal connections of genealogy between them. This scenario is precisely the reason why the concept of "kinds" is so important for the creationist argument: within "created kinds" creationists admit to genealogical descent and modification, but between kinds they do not. If one accepts this interpretation of the natural world, and virtually all those claiming to be "scientific creationists" do, then at least one prediction follows logically from its underlying assumptions:

Creationist Prediction 1: *The similarities observed among organisms cannot be shared so as to produce a hierarchical pattern of groups within groups.*

A corollary prediction, discussed in virtually all creationists writings, is:

Creationist Prediction 2: All morphological similarities shared between separate "created kinds" will exhibit strong correspondences in functions and biological roles that are tightly correlated with parallel ways of life.

First, let's examine the basis for these predictions. As noted earlier, creationists are predisposed toward the recognition of "created kinds" that are separated from each other by well-defined morphological gaps. But, as is obvious, the gaps are not complete—that is, distinctly different kinds of organisms share characters with one another. The creationists have erected an explanation to account for this (their explanation is the second prediction: that these similarities are a manifestation of functional design; this will be discussed below). Although creationists recognize the existence of shared similarities among disparate taxa and ascribe them to similarities in functional design, they also seem to realize that the assumption of creation would not lead one to expect a pattern of shared similarity that is consistently hierarchical in structure. On the other hand, modern comparative anatomy texts, with their admittedly evolutionary background, take note of this hierarchical pattern of similarity, and indeed it is a major prediction of the hypothesis that life evolved. In fact, such a pattern is less a prediction than it is a logical consequence of the evolutionary hypothesis; thus, it is not surprising that creationists have never claimed it as a prediction of their own world view. What is surprising, however, is that to my knowledge they have never stated explicitly the converse: that the *absence* of this pattern is a prediction of the creationist scenario. Among the creationists, Parker (1980) perhaps comes the closest to rejecting a hierarchical pattern. As an alternative, he suggests there is a "mosaic" pattern to the similarities among organisms. This is not a novel proposal, and through the history of systematics various workers have produced branching diagrams purporting to depict mosaic patterns of similarity (see the historical summary in Nelson and Platnick 1981). Mosaic representations of similarity relationships have been abandoned by the vast majority of biologists, and were by most of those who worked in preevolutionary times, for a very simple reason: hierarchical patterns convey more information and are

less ambiguous about the group membership of those taxa, which to most biologists appear to have objective "reality." In a nutshell, hierarchical patterns tell us more about nature than do mosaic patterns. Let's consider a simple example. As is well known, whales share many characters with terrestrial mammals: hair, mammary glands, a single bone in the lower jaw, etc. It is also possible to find some similarities between whales and, say, sharks: aquatic habits, fusiform bodies, and vertebral columns. If one treats this list of characters equally, then a mosaic pattern of similarity can be recognized. But one does not have to be an evolutionist to know that these characters are not all equal: hair, mammary glands, and a single bone in the lower jaw seem to be similarities shared by all animals we call mammals; a fusiform body seems to be a similarity shared by many animals that locomote rapidly through water; and a vertebral column seems to be a similarity shared by all animals we call vertebrates. Presumably Parker realizes that there exists a group that we call mammals—remember that his colleague Gish called mammals a "created kind"—and that whales are properly members of that group. And presumably Parker realizes that there is a still larger group called the vertebrates and that mammals are only one subgroup of them. If so, Parker and other creationists would have to admit to the logical conclusion that some similarities carry more significance than others for forming groups and that, as a result of these defining characters, these groups (such as mammals) have some objective reality. Barring a suspension of logical reasoning on their part, even creationists would then have to conclude that a hierarchical pattern is manifestly the most appropriate way of representing similarity relationships among organisms.

It would, of course, be possible for creationists to appeal to supernatural intervention to account for the existence of a hierarchical pattern of similarity—God might have, the creationists could argue, designed the world in just this way. On the other hand, it is unlikely that the creationists would want to take this form of argumentation, for two reasons: (1) the absence of this pattern would seem to be a logical outcome of a "creation event" that produced each "created kind" more or less simultaneously, which means that the creationists would then have to admit that their argument makes God appear illogical (Why would God create a pattern that appears to be the result of evolution?); and (2) the creationists ask—through their literature, public speaking, and legal

actions—that we judge their position vis-à-vis evolution on purely scientific grounds, which means that an appeal to the supernatural would seriously question the basis of “scientific creationism.”

The second prediction of the creationists is concerned with the problem of functional design. Thus, speaking of the shared similarities seen among different “created kinds,” creationists offer the following explanation:

Creationists, on the other hand, interpret the same similarities as evidence of common creative planning and design. The evolutionist has to assume all such characteristics have developed by chance mutations and natural selection. Creationists explain them as structures designed by the Creator for specific purposes, so that when similar purposes were involved, similar structures were created.

[Morris 1974, pp. 69–70]

Assuming that both creationists and evolutionists would agree that it is not possible to investigate scientifically the cause of a particular design being the result of some “creative force,” how are we to evaluate the creationists’ explanation of similarity? Empirically, what the creationists predict is that all similarities among “created kinds” are designs for similar ways of life. Can this prediction be tested and is it substantiated upon examination of cases in nature?

Personally, I doubt whether the creationists’ explanation of similarity—like much of the “adaptive” storytelling prevalent in evolutionary biology (Gould and Lewontin 1979; Cracraft 1981)—is rigorously testable. There are too many possibilities for differences of opinion over what should be identified as a similarity in morphology, a “purpose” (a function or a biological role), or a “way of life.” Thus, presented with an instance of falsification, a creationist might argue that the organisms being compared are not really similar. For example, one might observe that a very long, fusiform body is a similarity shared by many invertebrates, various diverse groups of teleost fishes, snakes, and some amphibians. No reasonable person would accept an argument that this similarity was “designed” in order that they might inhabit a similar way of life, and thus this similarity would seem to falsify the creationist prediction. Nevertheless, interminable arguments could be raised that upon detailed observation these bodies are not actually “similar” or perhaps that the

"purpose" of this similarity is actually the same for all (i.e., "locomotion") and that therefore we see a common design.

What can be concluded regarding creationism and the problem of design? The main point would seem to be that creationists should not invoke common design because not only are statements about similarity and functional design frequently too subjective and difficult to evaluate empirically, but they also are consistent with evolution as well. Evolutionists have traditionally interpreted morphological similarity as functional design for similar environmental conditions, but creationists are wrong when they assert that evolutionists must assume all similarities were produced "by chance mutation and natural selection." Such a claim merely reflects a superficial understanding of contemporary evolutionary biology and a narrow interpretation of evolutionary mechanisms. The concept of change being due to "chance" is philosophically and psychologically offensive to a creationist—it conjures up a world lacking purpose, direction, or design. But evolutionary change occurs not by "chance," if that word is taken to mean "at random," because the probability of evolutionary change in phenotype is not equal in all directions. The adult phenotype is the result of a highly regulated developmental (ontogenetic) history in which the phenotype is influenced not only by direct genetic controls over elaboration of biochemical products and their expression in developmental pathways, but also by epigenetic (environmental) factors modifying those pathways (Løvtrup 1974; Alberch 1980).

The development of organisms is thus canalized, or constrained; consequently, changes in the underlying genetic control or in environmental factors having an influence on ontogeny do not produce a random ("chance") array of phenotypic responses but rather a very narrow spectrum of possible alterations. In this way, then, much of evolutionary change can be viewed as being "directed" by developmental canalization, the exact direction being determined by a host of genetic and epigenetic factors.

Our increasing knowledge of developmental biology, and epigenetics in particular, is contributing to the view that developmental programs of different organisms may respond similarly if they are exposed to comparable environmental stimuli, even when those programs have differences in their genetic backgrounds (Løvtrup 1974; Alberch 1980). Thus, unlike the simplistic characterization of evolution proposed by the

creationists (and unfortunately, by some evolutionists) in which natural selection is envisioned as the primary, if not only, mechanism of directional change, modern evolutionary biologists are realizing that the magnitude and directionality of phenotypic change is primarily a problem of developmental genetics.

Returning to the main theme of this section, there is abundant evidence in the systematic literature for the existence of a natural hierarchy. This hierarchy is discoverable through the comparative analysis of derived similarities, and by far the best explanation for this hierarchy is that it represents the pattern of the phylogenetic history of life. It must be stressed that conjectures about the phylogenetic history of any particular group are scientific hypotheses that are subject to critical evaluation. Indeed, there is often much debate within the systematic community over which phylogenetic hypothesis best explains the available comparative data. Nevertheless, the relationships of many groups are well understood, leading to the conclusion that the existence of a natural hierarchy is as well corroborated as any hypothesis in biology.

Where does this leave the creationists? I suggest that the existence of a natural hierarchy refutes the creationist world view. To my knowledge they have never denied the existence of a hierarchy of similarity, nor have they provided a credible, scientific explanation as an alternative to descent with modification. I am unaware of a single paper in the scientific literature in which a creationist has attempted to refute the hypothesis of a natural hierarchy. Furthermore, inasmuch as systematic biology is the very cornerstone of evolutionary analysis (Eldredge and Cracraft 1980; Wiley 1981), it is significant that apparently no creationist is a professional systematist publishing in the scientific literature (to criticize the ideas in a field as complex as systematics, it is necessary to have a rather sophisticated understanding of those ideas).

The Natural Hierarchy and Intermediate Taxa

Creationists repeatedly assert that there are no taxa morphologically intermediate between major groups, and they use this claim as a cornerstone of their attack on evolution. A small sampling:

Transitional series *must* have existed in the past, if evolution is true, and the fossil record should reveal at least some of these. . . . The fact

is, however, that no such transitional series—or even occasional transitional forms—have ever been found in the fossil record.

[Morris 1977, p. 30]

If continuous evolution is a universal law of nature, as the evolutionist claims, then there should be an abundance of evidence of continuity and transition between all the kinds of organisms involved in the process, both in the present world and in the fossil record. Instead we find great gaps between all the basic kinds, and essentially the same gaps in the fossil record that exist in the modern world.

[Morris 1967, p. 34]

The history of life reveals a remarkable absence of the many transitional forms demanded by the theory [of evolution]. There is, in fact, a *systematic* deficiency of transitional forms between the higher categories, just as predicted by the creation model.

[Gish 1979, p. 70]

Many more similar quotations could be given. The “absence of transitional forms” argument could well be the paradigm example characterizing the entire creation-evolution controversy for it illustrates how creationists have taken an extremely complex scientific question, simplified the matter to the point of misrepresentation, and then have promoted the blatantly false claim that the fossil record supports the creationist world view. Indeed, from the manner in which creationists have discussed this issue, one can only conclude that either the creationists have consciously adopted the tactic of outright distortion or they are so abysmally ignorant of the scientific arguments and data that their apparent distortions are only accidental, not purposeful. In the short space available, I will attempt to summarize the problem.

After the publication of *On the Origin of Species* in 1859, paleontology assumed an increasingly pivotal role in documenting the evolutionary history of life, and examination of the fossil record itself was perceived as the most direct and efficacious method of historical analysis. At the time that Darwin was formulating his ideas on evolution, nature was being interpreted from a creationist point of view: species were seen as immutable “created kinds” and therefore as discrete entities. In posing an alternative to this world view, Darwin suggested that species

are not discrete, that what we observe presently as discrete species are only time-slices of an evolutionary continuum, and that there is a gradual transformation in phenotype through time. Placed in its historical context, this was a logical alternative to a theological interpretation of nature. Most importantly, the idea of a slow, gradual transition in form through time appealed to paleontologists, and ever since the search for these morphological transitions has been an important component of paleontological research (Eldredge and Gould 1972; Cracraft 1979). The contemporary paleontological view about the tempo of evolutionary change, and creationists' misunderstanding of it, will be discussed by Godfrey elsewhere in this book. Here, I want to focus on the nature of intermediate taxa, which are said to provide an evolutionary link between major groups.

Creationists have adopted three lines of argumentation against the existence of transitional forms: (1) they quote liberally from various paleontologists as to the paucity of transitional forms; (2) they define the concept of "transitional form" in a way that is distinctly different from the evolutionists' use of the term; and (3) they simply deny the existence of intermediate taxa, while ignoring a vast scientific literature opposing their position. I will discuss these in order.

In using selected quotations of paleontologists to buttress their own position, creationists have unwittingly entered one of the most controversial theoretical and methodological debates in contemporary paleontological systematics. Inasmuch as this debate has ensued for over a decade in the scientific literature, it is surprising that the creationists have not mentioned its existence (either the creationists are unfamiliar with the scientific literature or they have failed to understand the importance of that literature or they have simply chosen to ignore the problem and adopt a strategy that promotes their theological, not scientific, position). The debate centers on the scientific methods used to postulate and test hypotheses of ancestral-descendant relationship. Traditionally, paleontologists, including most of those quoted by the creationists, have had a conviction that the stratigraphic position of fossil taxa is a primary criterion with which to postulate ancestral-descendant relationships, whereas recent critics of this methodology have stressed the importance of a critical analysis of morphological characteristics (a summary of this literature can be found in Cracraft and Eldredge 1979; Eldredge and Cracraft 1980; and Wiley 1981). If the stratigraphic position of a fossil

are not discrete, that what we observe presently as discrete species are only time-slices of an evolutionary continuum, and that there is a gradual transformation in phenotype through time. Placed in its historical context, this was a logical alternative to a theological interpretation of nature. Most importantly, the idea of a slow, gradual transition in form through time appealed to paleontologists, and ever since the search for these morphological transitions has been an important component of paleontological research (Eldredge and Gould 1972; Cracraft 1979). The contemporary paleontological view about the tempo of evolutionary change, and creationists' misunderstanding of it, will be discussed by Godfrey elsewhere in this book. Here, I want to focus on the nature of intermediate taxa, which are said to provide an evolutionary link between major groups.

Creationists have adopted three lines of argumentation against the existence of transitional forms: (1) they quote liberally from various paleontologists as to the paucity of transitional forms; (2) they define the concept of "transitional form" in a way that is distinctly different from the evolutionists' use of the term; and (3) they simply deny the existence of intermediate taxa, while ignoring a vast scientific literature opposing their position. I will discuss these in order.

In using selected quotations of paleontologists to buttress their own position, creationists have unwittingly entered one of the most controversial theoretical and methodological debates in contemporary paleontological systematics. Inasmuch as this debate has ensued for over a decade in the scientific literature, it is surprising that the creationists have not mentioned its existence (either the creationists are unfamiliar with the scientific literature or they have failed to understand the importance of that literature or they have simply chosen to ignore the problem and adopt a strategy that promotes their theological, not scientific, position). The debate centers on the scientific methods used to postulate and test hypotheses of ancestral-descendant relationship. Traditionally, paleontologists, including most of those quoted by the creationists, have had a conviction that the stratigraphic position of fossil taxa is a primary criterion with which to postulate ancestral-descendant relationships, whereas recent critics of this methodology have stressed the importance of a critical analysis of morphological characteristics (a summary of this literature can be found in Cracraft and Eldredge 1979; Eldredge and Cracraft 1980; and Wiley 1981). If the stratigraphic position of a fossil

is an important criterion for recognizing it as an ancestor, it should come as no surprise that it would be extremely difficult to find a specific fossil species that is both intermediate in morphology between two other taxa and is also in the appropriate stratigraphic position. This is no doubt the reason for many of the quotes cited by the creationists about the prevalence of gaps, but other citations are distortions, tailored to suit the creationists' own purposes. For example, in 1972 Schaeffer, Hecht, and Eldredge published an influential paper in which they were critical of paleontological methodology about the construction of ancestral-descendant hypotheses. In support of his argument that there are no transitional forms, Gish (1979, p. 169) quoted from a review of that paper:

Three paleontologists (no less) conclude that stratigraphic position is totally irrelevant to determination of phylogeny and almost say that no known taxon is derived from any other.

[Van Valen 1973, p. 488]

Although the Van Valen quote gives the appearance of support for Gish's arguments against transitions, a reading of Schaeffer et al. (1972) shows that Van Valen is overstating their position. They clearly do not believe stratigraphy is "totally irrelevant" for examining ancestral-descendant hypotheses nor do they deny the possibility of identifying ancestral species. Rather than engage in a critical analysis of the scientific issues raised by Schaeffer et al., Gish prefers to use Van Valen's statement in a highly biased manner. Gish's unfamiliarity with the scientific literature adds irony to this example: Van Valen, perhaps more than any other contemporary paleontologist, has postulated innumerable phylogenetic connections among fossil taxa and thus offers the poorest support for Gish's viewpoint of anyone he could have misquoted.

Consider another example of distortion. In his discussion of gaps between major groups and the lack of apparent transitions, Gish states:

It cannot be emphasized too strongly that even evolutionists are arguing among themselves whether these major categories [*sic*; actually they are higher taxa, not categories] appeared *instantaneously* or not! It is precisely the argument of creationists that these forms *did* arise *instantaneously* and that the transitional forms are not recorded because they never existed! [1979, pp. 165-66; italics in original]

Because he is "strongly emphasizing" the debate among evolutionists over the rapidity of appearance of major groups of organisms, Gish should be familiar with some of the literature on the subject; yet he repeatedly misrepresents the concept behind "geologically instantaneous" to make it sound as if it is equivalent to "instantaneous creation." When paleontologists refer to the "instantaneous" origin of a major group, they mean that its appearance in the fossil record can be discerned over a time span that is very short relative to the entire record but that actually may span many millions of years in absolute time; furthermore, paleontologists emphasize that the component taxa of major groups do not all appear at once, as the creationist viewpoint would demand, but only that some of the major defining characters of the group are recognizable in the beginning (logically, this must be true or those fossils would not be assigned to the group in question). Gish knows creationists use "instantaneous" in a biblical sense (Gish and his colleagues at the Institute for Creation Research use six literal days), and he should know that he is misquoting paleontologists.

Creationists also define "transitional form" in such a way as to eliminate the possibility of ever finding one, and it is also a definition that evolutionists would find biologically unacceptable. They appear to envision a transitional form as one that is intermediate in all aspects of form between its immediate ancestor and its descendant. Consider this statement:

At the very least, there must have been a tremendous number of transitional forms between *Archaeopteryx* and its imaginary reptilian ancestor. Why does not one ever find a fossil animal with half-scales turning into feathers, or half-fore limbs turning into wings?

[Morris 1974, p. 85]

It is possible that creationists do not mean to imply that a transitional form should be intermediate in all respects, but if they do not mean this, then the only reasonable alternative is that transitional forms could be intermediate in *some* respects. If creationists admit this latter possibility, then there would be no reason not to expect the existence in the fossil record of a series of forms, each combining primitive characters inherited from its ancestors, with derived characters that are shared with other members of its lineage. Most modern evolutionists view the question of transitional forms in just this way; nevertheless, it is not difficult

to find isolated statements about the lack of intermediate forms. But the use of quotations is not an appropriate way to decide scientific issues, and if one examines the fossil record objectively, there is no doubt that intermediate taxa—mosaics of primitive and derived characters—exist for many major groups. Thus, for example, although *Archaeopteryx lithographica* does not appear to be a direct ancestral species of other birds, it is morphologically intermediate in many respects between reptiles and modern birds (Ostrom 1976). A second example: the evidence for a transition between cynodont reptiles and mammals is documented by intermediate fossil taxa, even though this is often denied by creationists (for a summary of the evidence, see Crompton and Jenkins 1979).

In summary, contrary to the protestations of the creationists, intermediate taxa exist for many groups. This does not necessarily mean, of course, that we have highly corroborated hypotheses about direct ancestral-descendant relationships of these taxa. Such a hypothesis is methodologically difficult to study. Nevertheless, when the phylogenetic patterns of the morphologically intermediate taxa are interpreted using modern comparative methods, these fossils present considerable evidence refuting creationist claims and supporting the evolutionary hypothesis.

Biogeography

The distribution of organisms has always played a central role in man's understanding of the history of life. Prior to the eighteenth century not much was known about the different kinds of organisms and their distribution around the world. Most of the knowledge was based on the ecology of those organisms living in Europe and neighboring regions. Because of their biblical background, naturalists of this time generally believed that the species they observed around them would be distributed pretty much worldwide, each according to its own special habitat requirements.

Once expeditions began exploring the world and knowledge accumulated, it did not take long to make the following observations, still true today: (1) there exists an incredible diversity of different kinds of organisms distributed in many areas of the world; (2) each area has its own unique kinds of organisms (it is rare, relatively speaking, for species to be very widely distributed); and (3) species in one area often show

similarity relationships to species in a distant area rather than to species in geographically closer areas.

These observations formed the basis for much scientific questioning; they constituted a pattern that biologists realized needed an explanation. The predominant explanation, promoted by many preevolutionary as well as postevolutionary biologists, was that organisms dispersed over the globe, developed differences in their respective areas, and then dispersed to other areas. Dispersalism has been, until quite recently, the primary explanation used by evolutionists (for a general historical summary, see Nelson 1978; and Nelson and Platnick 1981).

Modern biologists have always looked upon biogeography as one of the main sources of evidence for the evolutionary hypothesis. Indeed, biogeography presents such strong support for evolution that creationists have simply ignored the evidence rather than concocting outlandish stories based on revelation (major creationist writings not discussing biogeography include Morris 1974; Wysong 1976; Morris 1977; and Gish 1979). The reasons why biogeographical data present so many problems for the creationists are obvious: (1) they have to explain the great diversity of organisms; (2) they have to explain how all these different kinds of organisms were able to find their way to Noah so that they could avoid the Flood; (3) they have to explain how these different organisms found their way back to their respective areas (from high up on old Mount Ararat, no less); (4) they have to explain why most species (and higher taxa) are endemic to a restricted geographic area when a creationist scenario, in which taxa are dispersing from Ararat, would predict that most species would be widely distributed; and (5) they have to explain why widely separated areas seem to share related kinds of organisms.

From this list of problems, a critical reader should have no difficulty understanding why it is that creationists have ignored the evidence of biogeography. Either they must rely on revelation, pure and simple, or they are compelled to erect a "scientific explanation" that so strains one's credulity it makes them look patently silly. But creationists have an answer for everything. Consider the following examples, from Whitcomb and Morris (1961, p. 87), of their inexhaustible ability to rise to the occasion:

1. Whitcomb and Morris dismiss much of the data of biogeography merely by *ad hoc* argument, claiming that there was a "difference of

climatic and zoogeographical conditions before the Flood as compared to the postdiluvian area" (1961, p. 87).

2. And how did the animals get to the Ark and survive for more than three months (away from their native habitats)? By "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" (1961, p. 87).

3. What about after the Flood? Simple: "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" (1961, p. 87).

4. And how did these animals distribute themselves from Mount Ararat? Whitcomb and Morris, as do virtually all good creationists, offer a simple answer: "It would not have required centuries even for animals like the edentates to migrate from Asia to South America over the Bering land bridge. Population pressures, search for new homes, and especially the impelling force of God's command to the animals kingdom (Gen. 8:17) soon filled every part of the habitable earth with birds, beasts, and creeping things" (1961, p. 87).

Whitcomb and Morris wrote their book at a time when even many professional biogeographers clung to the idea that distribution patterns could be explained by massive waves of dispersal. Nevertheless, the most ardent dispersalist would never accept the idea that all the animals dispersed from Ararat to the far corners of the globe, and differentiated into a myriad of forms, within a few thousand years. That scenario is childish myth—it is fundamentalistic religion, not science.

During the last decade biogeographers have come to realize that when the postulated phylogenetic relationships of organisms—both plants and animals—are examined relative to their distributions, many highly congruent, nonrandom patterns emerge. Many of the taxa endemic to tropical South America have as their closest relatives taxa endemic to Africa; taxa endemic to the cool temperate regions of southern South America have as their closest relatives taxa endemic to New Zealand and the cool temperate regions of Australia and Tasmania; and some taxa endemic to western North America have as their closest relatives taxa endemic to China and eastern Asia; and so on. Given these many patterns of distribution, it has become apparent that biotas now separated were once connected and that after separation the individual

components (taxa) of these biotas differentiated in isolation. In other words, dispersal from one area to another, followed by differentiation, is apparently not as important as once thought. And as biogeographers study the problem in more detail, it is becoming apparent that these patterns of biotic separation are correlated with changes in earth history, continental drift being the most obvious example. The literature on this new approach to distribution, called vicariance biogeography, is already very large and promises to change many of our ideas about the history of life (see Platnick and Nelson [1978]; Nelson and Platnick [1980, 1981]; Cracraft [1980]; and Nelson and Rosen [1981]).

While professional biologists struggle with the enormous complexity of the systematic relationships of organisms, their distribution patterns, and the correlation of those patterns with hypotheses about earth history, creationists take the easy road to "knowledge" and simply force a biblical interpretation on nature. The most detailed biogeographic analysis by a creationist in recent years is that of Howe (1979), who attempts to "explain" the distribution of angiosperms. Let's examine his method of analysis:

1. Howe informs us (p. 38) that plants present "an array of unrelated types," a ludicrous assertion in this day and age. If Howe were working in a monastery in the fourteenth or fifteenth century he might be excused, but no modern scientist with any competence could make that statement. Of course, he ignores the large literature on plant systematics.

2. He proclaims (p. 41) that in angiosperms the genus is probably the "created kind," but presents no evidence informing us how he made that decision.

3. He interprets (pp. 40-43) endemics as having been isolated by Flood-related events, particularly by continental drift, which is said to have occurred *after* the Flood. This is so manifestly silly as to require little comment. Any person claiming that the vast literature on plate tectonics and continental drift supports a time scale for these events on the order of a few thousand years is suffering a delusion of religious faith and is definitely not gifted with any faculties for scientific reasoning.

Howe is a typical example of extreme creationist thinking and reasoning when it comes to biogeographic data: ignore the evidence, claim that the evidence (which you have ignored anyway) fits a literal interpretation

of Genesis, and then claim that what you are doing is science. Who can take such a view seriously?

Classification

In biology, formal classifications have existed primarily as a means of expressing the content of natural groups. Since Darwin, most biologists have taken these groups to be those descended from a common ancestor. The precise content of natural groups is a scientific hypothesis. Thus, alternative hypotheses could be proposed for the content of natural groups. It might be supposed, to mention an example used earlier, that whales should be classified with sharks rather than with mammals. Also, a hypothesis about the content of a natural group is predictive and therefore testable. These hypotheses make predictions about the hierarchical distribution of similarities shared among the organisms in question. Classificatory hypotheses such as this have been made for a very long time and have been discussed in detail in the systematic literature (see especially Eldredge and Cracraft 1980; Nelson and Platnick 1981; and Wiley 1981).

Because systematists are scientists, there are bound to be considerable differences of opinion about the theory and methodology of biological classification. A large literature exists on the subject, and differences of opinion continue to be expressed in the technical journals, including *Systematic Zoology* and *Systematic Botany*. Creationists have commented on classification, but it is obvious from their statements that they are not interested in the scientific aspects of classification, but rather in how that literature can be used to support creationism. Some typical comments:

Actually, the more confusion in classification—the less organisms are distinctly demarcated—the more it will appear as though organisms blend into one another, i.e., the more evolution will appear true.
[Wysong 1976, p. 58]

The fact that categories of natural phenomena can be arranged in orderly classification systems (table of chemical elements, biological taxonomy as in the Linnaean system, a hierarchy of star types, etc.) is a testimony to creation. That is, if all entities were truly in a state

of evolutionary flux, classification would be impossible. In biological classification, for example, it would be impossible to demark where 'cats' leave off and 'dogs' begin. [Morris 1974, pp. 21-25]

The arguments of Wysong and of Morris and his colleagues are straw men of their own manufacture. Only the creationists claim that there must be an unbroken, gapless chain of morphology if evolution is true—evolutionists certainly do not think this; consequently, their arguments vanish. Inasmuch as they provide little indication of having read the scientific literature on classification theory, they are probably unaware that many biologists, who nevertheless accept evolution, advocate classifications that do not necessarily express evolutionary relationships. There are thus many ways to classify.

Most biologists, however, do advocate that classifications be expressive of phylogenetic relationships to a greater or lesser degree, and the creationists use these classifications themselves. If they believe these are arbitrary (e.g., Morris 1974, pp. 71-72), one would think they would prefer their own classification to that of the evolutionists. And if they attempted such a classification, chances are they would adopt most of the same groups as the evolutionists. Why should that be? Because these groups share defining similarities: the derived characters of the evolutionist. Linnaean classification schemes, used throughout biology, express the pattern of hierarchical similarity discussed earlier, and the reason seems to be that nature is hierarchical—a prediction of evolution, not creationism.

Discussion

It is a depressing situation when biologists of the late twentieth century find it necessary to answer challenges to evolutionary science by a small group of religious zealots. This is especially so since the issues are not really scientific in content, but rather are sociological, political, and economic. The arguments of the modern-day creationists hark back to a time, hundreds of years ago, when superstition and religious dogma controlled—or attempted to control—peoples' lives and intellectual activities: it is easier to believe the truth of religious dogma than to seek rational understanding, easier to believe than to question, easier to be told what to know than to decide for oneself.

I say that the present controversies are sociological and political rather than scientific because the creationists evidence so little understanding of modern biology, and evolutionary biology in particular, that they could not be expected to carry on an intelligent dialogue on the scientific issues. The main reason for this, of course, is their commitment to conservative, religious fundamentalism, rather than to the pursuit of knowledge. Naturally they will seek a degree of understanding only sufficiently deep to accept that which reinforces their own psychological and philosophical belief system. In the final analysis, all arguments of the creationists come back to religious dogma, and despite an intense political campaign to convince the public that they are unbiased, critical scientists, it is common knowledge, at least among scientists, that that campaign is founded almost entirely on their attempts at establishing the legitimacy of their self-manufactured rubric "scientific creationism." This judgment is not intended to question the sincerity of the motives or beliefs of the many nonscientists who undoubtedly evaluate the world around them from deep, personal supernaturalistic faith. The leadership of the "scientific creationist" movement, on the other hand, frequently has exceeded the boundaries of this faith to proselytize creationism by criticizing evolutionary biology with innuendo, distortion, and outright deception. Such has to be the judgement of their writings on evolution, unless one wants to accept the only viable alternative hypothesis: that these writings manifest a sincere form of religious zeal and ignorance of the scientific issues.

In this chapter I have tried to show how creationists use the data of systematics and comparative biology. One might ask how this use can be characterized from a scientific standpoint, and the answer would be unequivocal: superficial and unprofessional. This may or may not be unexpected, depending upon how much time one spends critically reading their writings rather than listening to their self-proclamations about their credentials and qualifications. Creationists complain incessantly about the impossibility of getting their writings published in the scientific literature (many people do not realize that virtually all their publications are produced by their own organizations). The truth of the matter is that, if the writings quoted here are characteristic of their understanding of the scientific issues, the creationists would seem to have nothing to say that is of any scientific value. It is their lack of competence, rather than prejudice on the part of evolutionists, that prevents them from

publishing. Indeed, there are many devout Christians who regularly publish in the scientific literature, but they promote competent science, not religion disguised as science.

As I have demonstrated in this chapter, creationists offer explanations of natural phenomena (distribution patterns, for example), the only content of which is strict adherence to and belief in the literal truth of Genesis. This immediately disqualifies these explanations as being scientific. The use of the term "scientific creationism" is a charade, and is merely the political propaganda of a conservative, fundamentalist belief system.

Creationism could easily be ignored as a manifestation of a religious cult or fringe group if it were not for its potential to become more broad-based within Christian fundamentalism. Those creationists cited in this chapter are extremists; they cannot be allowed to convince sincere Christians that their religious faith will be destroyed by knowledge derived from science and the humanities. Personal choice and belief will maintain that faith, if one so chooses. But the attitudes of the creationists constitute a threat to critical inquiry and to the growth of knowledge. The reason for this is simple: as long as you think you have the truth, you will feel no need to pursue knowledge and understanding. The creationists have their truth, and they want to convey that truth through indoctrination:

Only the Creator—God himself—can tell us what is the truth about the origin of all things. And this He has done, in the Bible, if we are willing simply to believe what He has told us. [Morris 1967, p. 20]

If we expect to learn anything more than this about the Creation, then God above can tell us. And He has told us! In the Bible, which is the Word of God, He has told us everything we *need* to know about the Creation and earth's primeval history.

[Morris 1967, p. 54; italics in original]

The final and conclusive evidence against evolution is the fact that the Bible denies it. The Bible is the Word of God, absolutely inerrant and verbally inspired. . . . The Bible gives us the revelation we need, and it will be found that all the known facts of science or history can be very satisfactorily understood within this Biblical framework.

[Morris 1967, p. 55]

These are the words of Henry Morris, director of the Institute for Creation Research, perhaps the most influential creationist organization. If one agrees with him, then what I have written will not make much sense or difference. If, on the other hand, one does not necessarily want Henry Morris to decide what one needs to know, then perhaps what I have written will be useful in evaluating the cogency of creationist thinking.

REFERENCES CITED

- Alberch, Pere. 1980. Ontogenesis and morphological diversification. *American Zoologist* 20:653-67.
- Cracraft, Joel. 1979. Phylogenetic analysis, evolutionary models and paleontology. In *Phylogenetic analysis and paleontology*, ed. Joel Cracraft and Niles Eldredge, pp. 7-39. New York: Columbia Univ. Press.
- . 1980. Biogeographic patterns of terrestrial vertebrates in the southwest Pacific. *Palaeogeography, Palaeoclimatology, Palaeoecology* 31:353-69.
- . 1981. The use of functional and adaptive criteria in phylogenetic systematics. *American Zoologist* 21:21-36.
- Cracraft, Joel and Eldredge, Niles, eds. 1979. *Phylogenetic analysis and paleontology*. New York: Columbia Univ. Press.
- Crompton, A. W. and Jenkins, Farish A., Jr. 1979. Origin of mammals. In *Mesozoic mammals: the first two-thirds of mammalian history*, eds. Jason A. Lillegraven, Zofia Kielan-Jaworowska, and William A. Clements, pp. 59-73. Berkeley and Los Angeles: Univ. of California Press.
- Darwin, Charles. 1859. *On the origin of species by means of natural selection, or the preservation of favored races in the struggle for life*. Facsimile edition (1975). Cambridge, Mass.: Harvard Univ. Press.
- Eldredge, Niles and Cracraft, Joel. 1980. *Phylogenetic patterns and the evolutionary process*. New York: Columbia Univ. Press.
- Eldredge, Niles and Gould, Stephen J. 1972. Punctuated equilibria: an alternative to phyletic gradualism. In *Models in paleobiology*, ed. T. J. M. Schopf, pp. 82-115. San Francisco: Freeman, Cooper and Co.
- Gish, Duane T. 1979. *Evolution? The fossils say no!* 3rd ed. San Diego: Creation-Life Pubs.
- Gould, Stephen J. and Lewontin, Richard C. 1979. The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme. *Proceedings of the Royal Society of London* 205B:547-65.
- Hennig, Willi. 1966. *Phylogenetic systematics*. Urbana, Ill.: Univ. of Illinois Press.
- Howe, G. F. 1979. Biogeography from a creationist perspective. I: taxonomy,

- geography, and plate tectonics in relation to created kinds of angiosperms. *Creation Research Society Quarterly* 16:38-43.
- Lack, David. 1947. *Darwin's finches*. Cambridge, Eng.: Cambridge Univ. Press.
- Lammerts, William E. 1970. The Galapagos Island finches. In *Why not creation?*, ed. William E. Lammerts, pp. 354-66. Grand Rapids, Mich.: Baker Book House.
- Løvtrup, Søren. 1974. *Epigenetics*. New York: Wiley.
- Marsh, Frank Lewis. 1947. *Evolution, creation and science*. Washington, D. C.: Review and Herald Pub. (not seen; quoted by Wysong 1976, p. 59).
- Mayr, Ernst. 1963. *Animal species and evolution*. Cambridge, Mass.: Harvard Univ. Press.
- Morris, Henry M. 1967. *Evolution and the modern Christian*. Philadelphia: Presbyterian and Reformed Pub. Co.
- . 1974. Ed. *Scientific creationism*. San Diego: Creation-Life Pubs.
- . 1977. *The scientific case for creation*. San Diego: Creation-Life Pubs.
- Nelson, Gareth J. 1978. From Candolle to Croizat: comments on the history of biogeography. *Journal of the History of Biology* 11:269-305.
- Nelson, Gareth J. and Platnick, Norman I. 1980. A vicariance approach to historical biogeography. *Bioscience* 30:339-43.
- . 1981. *Systematics and biogeography: cladistics and vicariance*. New York: Columbia Univ. Press.
- Nelson, Gareth J. and Rosen, Donn E., eds. 1981. *Vicariance biogeography: a critique*. New York: Columbia Univ. Press.
- Ostrom, J. H. 1976. *Archaeopteryx and the origin of birds*. *Biological Journal of the Linnean Society* 8:91-182.
- Parker, Gary. 1980. *Creation: the facts of life*. San Diego: Creation-Life Pubs.
- Platnick, Norman I. and Nelson, Gareth J. 1978. A method of analysis for historical biogeography. *Systematic Zoology* 27:1-16.
- Schaeffer, B., Hecht, M. K., and Eldredge, N. 1972. Phylogeny and paleontology. *Evolutionary Biology* 6:31-46.
- Siegler, Hilbert R. 1978. A creationists' taxonomy. *Creation Research Society Quarterly*, 15:36-38.
- Van Valen, Leigh. 1973. Review of *Evolutionary Biology*, vol. 6. *Science* 180: 488.
- Whitcomb, John C., Jr. and Morris, Henry M. 1961. *The Genesis flood*. Grand Rapids, Mich.: Baker Book House.
- Wiley, Edward O. 1981. *Phylogenetics: the theory and practice of phylogenetic systematics*. New York: Wiley.
- Wysong, R. L. 1976. *The creation-evolution controversy*. Midland, Mich.: Inquiry Press.