EDITORIAL

HISTORICAL SCIENCE

In the acrimonious controversy between creationists and evolutionists, some scientists have stated that the general theory of evolution is as much a fact as other well-established principles of science such as gravity. As expected, such statements evoke varied reactions. Some feel comfortable with these because both gravity and evolution are naturalistic phenomena which are within the current concepts of science. On the other hand, others see a significant difference in the degrees of validation possible for these two concepts.

Most of us became acquainted with the realities of science by performing experiments in the laboratory and arriving at the expected results. This gave us great confidence in the scientific method. The outcome of experiments could be predicted. Of course, occasionally the results did not come out as expected, and the malfunction was usually explained in terms of faulty procedure, inaccurate measurement, contamination, etc., but not as indicating possible alternative interpretations of science. These basic experiments helped establish in our minds the idea that science is an absolute and that if things go amok the fault is due to anything except science.

There is ample evidence to support the predictability of simple laboratory experiments. It is regrettable that the contrast between these well-tried experiments and the unknowns of more investigative scientific endeavors are seldom appreciated by the general public or even by some trained scientists. Science is envisioned as a simple, sure procedure. We have all met that young visionary scientist who is enthusiastic about his new-found discipline and its potential for advancing human knowledge, but he has not yet acquired the caution that comes from experience. He does not yet appreciate that what we glibly call the “advancing frontiers of knowledge” also represents the “edge of ignorance.”

Some scientists have attempted to alleviate the contrast between degrees of confidence in science by isolating some of the less sure areas of science under the designation of historical science. As with other broad concepts, historical science cannot be simply defined. It is not to be confused with the historian’s use of the same term to describe a methodological concept. As used by scientists, historical science refers especially to those aspects of science which are not as easily testable and predictable because they are more unique at least within the limits of practicality. They often represent concepts about the past, hence the historical connotation in the designation. Physics and chemistry are usually considered less historical; geology, biology and paleontology more so. This difference is due in part to the complexity of the factors under consideration — physics and chemistry being the simplest and most predictable, while biology and paleontology which deal with a vast complex of interacting factors present more uncertainties. Nevertheless, it is mainly around the problems of testing past unique events that the concept of historical science has developed. Unique events are difficult to analyze scientifically; unique past events are even more difficult. In the historical sciences, opportunity for speculation is greater and caution more appropriate. The warning in the statement that “God cannot alter the past, but historians can” is likewise applicable to historical science.

A significant number of the great controversies in science have centered around historical science issues. Given the difficulty in testability, this is expected. Some of the major battles include: 1) Concepts of the age of the earth changing from the 17th-century ideas of a few thousand years to Kelvin’s estimates of less than 100,000,000 years to contemporary concepts of several billion years, 2) The change from the Neptunist’s ideas that the crust of the earth was formed mainly by the action of water to ideas involving plutonic and volcanic concepts, 3) Ideas in the 17th century that life arose spontaneously, to the work of Louis Pasteur last century denying it and then back to spontaneous generation again in modern studies of abiogenesis, 4) Denial to acceptance of the ice ages, 5) Acceptance of catastrophism for the past history of the earth followed by total rejection for over a century, then again acceptance of a modified catastrophism, 6) Replacement of belief in the fixity of the continents by the present concepts of continental drift and plate tectonics, 7) Current contentions in anthropology regarding the purported evolutionary ancestral pattern for man, 8) The evolution versus creation controversy. Thus it appears that the uncertainty of historical science has provided its share of controversy.

One of the lessons to be learned is that we should not confuse the success of what we can call immediate science with the tentativeness of historical science. Our science is not as good when dealing with the past because of unknown changes that occur with time. The further one goes back, the more difficult it can become to relate the present to what may have happened long ago. Caution warrants that immediate and historical science each be kept in its proper sphere of evaluation. Evolution, classical uniformitarianism, catastrophism, or creation, etc., may be considered to be on a par with immediate science by some, but more appropriately these are historical sciences.

The success of immediate science should not be used as an excuse to bolster the inadequacies of historical science by ignoring the difference between the two. Science can provide information related to these “historical” concepts, but the difference in the degree of scientific validation between immediate and historical science should be recognized. Because of this, one should not say that the general theory of evolution is as much a fact as gravity.

Ariel A. Roth

REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

Re: Evard: A Candid Reevaluation (ORIGINS 11:101-102) and Javor: Life, An Evidene for Creation (ORIGINS 11:105-108).

Rene Evard's review of *The Mystery of Life's Origin: Reassessing Current Theories* gave a fair overview of the book by Thaxton, Bradley, and Olsen. But without reading it, one cannot appreciate the impact of the evidence they present for the improbability and impracticality of chemical evolution. It is always shaky business to argue from absence of evidence, or failure to achieve an effect. Yet that is essentially the status of chemical evolution presented by this book: failure to achieve effects that are congruent with one another within the scenario of chemical evolution.

Thaxton et al. are not pretending to have disproven the concepts of chemical evolution. Nor do they in the presentation of alternative solutions to the origin of life advance Special Creation as the only (proven) means. Rather, they present "a line of reasoning to show that Special Creation by a Creator beyond the cosmos is a *plausible* view of origin science" (p. 212 of their book, emphasis mine).

It is in this same spirit that G. T. Javor's lovely testament, "Life, An Evidence For Creation," asserts that "Our knowledge of life from the *evidence at hand* argues against the notion of nonliving matter organizing itself spontaneously into life forms under any conditions at any time" (emphasis mine). He poses similar questions to those explored by Thaxton et al. regarding the source of information and energy necessary for meaningful organization of biopolymers. And the conclusion, at present, is the same: we have no sufficient knowledge to show how living matter arises from nonliving.

Surely we who practice science will never be satisfied with a "God did it" attitude that squelches research. The quest for knowledge cannot be stopped, anymore than the premonition of misuse of a new discovery can stop its eventual disclosure. The problem is that we have no alternative but *plausible* arguments.

In our zest for synthesis we build models that contain our present level of understanding. As these prove inadequate the models are revised, or discarded and replaced altogether. But when a collection of models fit so poorly, as Thaxton et al. portray the case for chemical evolution, and the revisions of these models seem exhausted, then one is inclined to discard the models. If replacement is not forthcoming, the only choice left is a plausible argument, and it may be one whose source is outside of science! I believe this is the basic message of both Thaxton et al. and Javor.

This is not to say that research into the origin of life is unscientific or that it is founded on mere speculation. But that this kind of research must be satisfied to show what is not, rather than what is. By exhausting the capacity of scientific models, Thaxton et al. and Javor are saying that "God did it through Special Creation" is plausible.

I'm going to stick out my neck and say that valid scientific modeling may begin with this premise. If you cannot reject the null hypothesis, but neither can you accept any of the alternative hypotheses, then the null hypothesis becomes plausible. Such is the case for Special Creation in its role as null hypothesis

The Apostle Paul goes a step further and makes "God did it" an axiom. "For the invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, ¼ so that [we] are without excuse" (Romans 1:20). Axioms are self-evident statements, not subject to verification by the system of theorems deduced from them. By including the axiom (from outside science) the scientist who accepts the plausibility of Special Creation is acknowledging that within his science logical inconsistencies can arise that can be resolved only with premises that originate outside the system. (This is the scientific equivalent of Kurt Goedel's theorem in mathematics.)

Thus we should press on with our modeling, both evolutionary and creationistic. The Special Creationist who includes Paul's axiom in his thinking will have to show that its inclusion has not prejudiced his scientific objectivity. The evolutionist must recognize that the best he can hope to do is reject unworkable hypotheses. Both must be willing to acknowledge plausible explanations of life's origin.

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Re: News and Comments — The Louisiana Balanced-Treatment Act (ORIGINS 12:38-40).

On p 40, 4th paragraph from top of page, isn't there an oxymoron ("religious and therefore unscientific") in the judge's pronouncement in his summary judgment? — "Balanced-Treatment Act a violation of the establishment clause because THE CONCEPTS OF CREATION AND A CREATOR ARE NECESSARILY RELIGIOUS AND THEREFORE UNSCIENTIFIC." Aren't religion and science both concerned with truth or pursuit of truth and should either side be permitted to pre-empt ground without laboratory proof, so it cannot even be explored by the other? It seems to me that it that is the case it should cut both ways.

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ARTICLES

A CREATIONIST VIEW OF CHROMOSOME BANDING AND EVOLUTION

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WHAT THIS ARTICLE IS ABOUT

Similarities in organisms are commonly interpreted as the result of a common ancestry. Since chromosomes are the carriers of heredity, similarities in chromosomes could have special significance in studying the ancestry and relationships of species. Many studies comparing chromosomal banding patterns have been conducted. Through the use of a special staining technique, chromosomes can be stained to show a pattern of alternating dark and light bands. The detail of the pattern depends on the length of the chromosome at the time it is stained. If sufficient detail is present, each pair of chromosomes in a cell can be distinguished. Chromosomes from different species can be stained and then compared and contrasted. Similarities and differences maybe interpreted subsequently as reflecting the degree of relationship.

Although there are some interesting exceptions, comparisons of chromosomal banding patterns are generally consistent with comparisons based on other criteria. Species within a family generally show considerable matching of chromosome banding patterns. The cat, camel, and cow families each have substantial intrafamilial similarities in chromosomal banding patterns. On the other hand, some species have banding patterns which differ greatly from those of other species in the same genus. Similar species with different chromosomal banding patterns are found among certain deer (the muntjacs) and bats (Family Phyllostomidae).

More problematic are the similarities in chromosomal banding patterns among species which are different in structure. Interfamilial chromosomal banding similarities are found among the cats, mongooses, and raccoons; among the cow, deer, and giraffe families; among several families of marsupials; and among several families of primates, including humans. This raises questions about the extent of change which may have occurred in mammals, as well as the relationship of humans to other primates.

Four hypotheses to explain similarities of chromosomal banding are discussed in this paper. Such similarities could be the result of common design, of common ancestry, of chance, or of the action of virus-like agents. The hypothesis that chromosomal similarities could be due to chance seems unreasonable, It seems more likely that virus-like agents would cause differences between karyotypes than that they would change different karyotypes to look similar. Common ancestry appears to be the most likely basis for chromosomal similarities in species classified in the same genus, and for some species classified in different genera. However, to extend this explanation to higher taxonomic categories, in which similarities are of lesser extent and of lower quality does not seem necessary. To a creationist, it seems more probable that chromosomal similarities such as are found

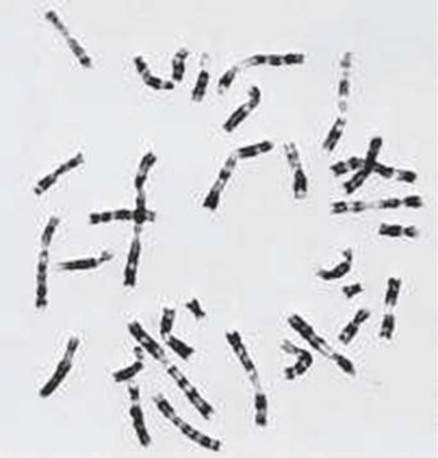
within the artiodactyls, the carnivores, the marsupials or the primates may be the result of common design.

INTRODUCTION

The genetic instructions for an organism are located in the chromosomes of the cells of the organism and are transmitted to the offspring by inheritance. A logical prediction of evolutionary theory is that closely related species should have similar chromosomes. Techniques of chromosome banding have now been available for a long enough period of time that some trends have been discovered, and the results can be examined profitably.

Comparisons of *karyotypes* (sets of chromosomes) can be based upon differing levels of detail (see White 1978:47). The first comparisons were made on the basis of the number of chromosomes. In some cases the number of one-armed (acrocentric) and two-armed (metacentric) chromosomes were included in the comparison, and the sex chromosomes were identified. Extensive lists of chromosome counts can be found in Matthey (1973a,b) for placental mammals and in Sharman (1973) and Hayman (1977) for marsupials. However, attempts to infer relationships based upon unbanded karyotypes have not been satisfactory (Atchley 1972). Frequently, individual chromosomes could not be identified, making comparisons of uncertain validity. Differences in arm number due to gain or loss of *heterochromatin* (tightly condensed chromatin, generally considered to have little genetic activity) were not correctly interpreted using conventional staining (Duffy 1972).

FIGURE 1. An example of a chromosome spread showing Giemsa banding. The spread illustrated is from a Columbian ground squirrel (*Spermophilus columbianus ruficaudus*).



The development of banding techniques overcame these difficulties and made comparisons more meaningful. Structural changes in chromosomes (chromosomal rearrangements) can now be identified precisely. However, much remains to be learned about the meaning of banding and the structure of chromatin (the chromosomal material), and further developments can be expected to add to the value of comparative karyology. Several methods of chromosomal banding are available, but the most widely used method is G-banding (Giemsa-banding). This technique produces a characteristic pattern of contrasting dark and light transverse bands on the chromosomes (see Figure 1). The banding pattern is different for nearly all species studied, although sometimes the differences are slight. A large number of mammal species have been G-banded, but the number of species remaining to be studied is much larger.

PURPOSES OF COMPARISONS

Homeology

Comparisons of banding patterns often reveal nearly identical patterns in closely related species. The corresponding bands are believed to be homologous, but to allow for minor genetic difference, the term "homeology" is often used (e.g., Dutrillaux, Couturier & Fosse 1980).

Chromosomal similarities have been noted between groups of species in different genera or higher taxonomic categories. A significant degree of homeology has been found among all three families of seals (Arnason 1977). Homeologies at the suborder level have been noted within the primates (e.g., Dutrillaux, Couturier & Fosse 1980). Comparison of cat and human banding patterns (Nash & O'Brien 1982) did not show significant banding homeologies, although their gene mapping studies suggest similar gene arrangements (O'Brien & Nash 1982). Claims of banding homeologies between primates and carnivores by Dutrillaux & Couturier (1983) are of uncertain validity, because the proposed homeologies are based on portions of chromosome arms with a small number of bands involved. Reliable homeologies should include entire arms or be supported by other evidence (see Ponsa et al. 1981).

The actual genetic homology of similar banding patterns is supported by comparative gene mapping. Genes for equivalent enzymes are indeed often present on chromosomes with similar banding patterns in different species (Lalley & McKusick 1985). Genes which are found close together on a chromosome are said to be linked. Groups of genes which are linked in humans are generally also found linked in other species. In fact, gene groupings appear to be similar in many species even when chromosome banding homeology has not been detectable (Nash & O'Brien 1982, Kiel et al. 1985). Several equivalent linkage groups have been found on chromosomes with similar banding patterns in humans and other primates (Lalley & McKusick, loc. cit.). Several linkage groups are also common to human and cat chromosomes; in fact, the similarities in linkage patterns between cats and humans are almost as consistent as between chimpanzees and humans (O'Brien & Nash 1982), although based on fewer gene loci. Several mouse linkage groups are similar to human linkage groups, if one allows for the correspondence of one two-armed human chromosome with two one-armed mouse chromosomes. Whether the genes controlling such characteristics of organisms as development and morphology are also linked in similar ways in similar species is not known.

Classification

Comparative studies of chromosomal banding patterns have been useful in classification. Sibling species are species which appear alike morphologically, but have been discovered to be reproductively isolated. Giemsa-banding is not necessary to detect sibling species, but it can assist in identifying the differences between the species more precisely. Chromosomal sibling species have been discovered within cotton rats (*Sigmodon*; see Elder 1980), grasshopper mice (*Onychomys*; Hinesley 1979), and shrews (*Sorex*; Olert & Schmid 1978).

The use of G-banding has sometimes been helpful in clarifying the taxonomic position of species which do not have clear affinities based on other characters. Chromosomal differences have been used in determining the taxonomic placement of the African rat *Mastomys* (Lee & Martin 1980), the golden mouse (*Ochrotomys*; Engstrom & Bickham 1982), and *Neotomodon alstoni* (Yates, Baker & Barnett 1979). The giant panda, *Ailuropoda*, has been variously classified with the bears, raccoons, or in a family by itself. Although previous researchers were unable to find good banding matches (Wurster-Hill & Bush 1980), a more recent study (O'Brien et al. 1985) identified several banding matches linking the giant panda with the bears. The authors conclude by suggesting the giant panda be classified in a separate subfamily within the bear family Ursidae.

Sometimes chromosomal comparisons give unexpected results. For example, the karyotypes of some South American genera of rodents were more like the karyotypes of wood rats (genus *Neotoma*) a primarily North American genus, than they were like the karyotypes of cotton rats (*Sigmodon*), a primarily South American group (Baker, Koop & Haiduk 1983).

The validity of using chromosomal banding comparisons to assist in determining degree of relatedness was supported in a study by Mascarello, Stock & Pathak (1974). The banding pattern of a species of woodrat (*Neotoma*) was compared with that of six other rodent species, progressively more distantly related taxonomically. The degree of matching was near total for another woodrat species from the same subgenus and showed a general decrease in comparison with species of increasing taxonomic distance. About one-third of the chromosomes matched those of species from other tribes or subfamilies. Comparison with a species of kangaroo rat (*Dipodomys*, different superfamily) revealed no detectable banding homeologies with the woodrat. These results show general agreement with traditional methods of classification.

Constructing Phylogenies

Giemsa banding has made possible the identification of specific chromosomes involved in rearrangements (Seabright 1972), permitting one to determine whether similar species possess the same rearrangement. Shared chromosomal rearrangements in similar species are interpreted as evidence of a common ancestor which had the rearrangement (see Rofe 1976). Several species of antelopes which share a Y/autosome translocation provide one such example (Benirschke et al. 1980).

The ability to identify similar banding patterns in different species and to identify chromosomal rearrangements has led to interest in reconstructing the historical sequence of rearrangements which have accompanied speciation in a group of species (see Spotorno 1977). The construction of such "family trees" is based on several assumptions. One assumption is that the ancestral karyotype can be determined with reasonable accuracy. This requires that the species to be compared be chosen carefully (Dutrillaux & Couturier 1983) and that homeologies be accurately identified. Another assumption is that the best tree is one which requires the fewest reversals and convergences (principle of parsimony; see Farris 1978).

The method is not without difficulties. One problem is that reversals and convergences do occur (e.g., see Baker, Barnett & Greenbraum 1979; Baker, Koop & Haiduk 1983; Searle 1984), probably because certain points on a chromosome are more susceptible to breakage than other points (Bush 1981, Nevers & Saedler 1977). Another problem is the possibility of mismatches, especially when only portions of chromosomal arms are involved (see Ponsa et al. 1981). Despite these difficulties, cladograms ("family trees") based on chromosomal characters are useful in testing for congruence with cladograms based on other data.

Cladograms based on chromosomal characters have been constructed for groups at several taxonomic levels, for example the genus *Peromyscus* (Robbins & Baker 1981), the bovid tribe Tragelephini (Benirschke et al. 1980), and several genera of murid and cricetid rodents (Koop et al. 1984). An especially comprehensive study at the superfamily level has been done for phyllostomoid bats (Patton & Baker 1978). Obviously, such cladograms cannot be more accurate than the identification of banding homeologies.

RESULTS OF COMPARATIVE G-BANDING STUDIES

This section discusses numerous examples of studies in which banding patterns of various species have been compared. It forms the basis for the discussion in the next section (Creationist Viewpoint). Readers not interested in details may skip to the next section, referring to this section only if more details are desired. No attempt is made here to present an exhaustive list of references on G-banding results in mammals. Instead, I will discuss briefly a sample of the literature available, emphasizing studies of special interest or taxonomic breadth. Preference is given to papers which compare the banding patterns among several species or higher categories.

Monotremes

The taxonomic relationships of the egg-laying mammals are somewhat uncertain, as they show some skeletal similarities with reptiles and others with mammals (see Nowak & Paradiso 1983:1). There are three living genera, divided into two families. The anatomical uniqueness of the species is paralleled by the unusual nature of the karyotypes. The platypus has 52 chromosomes in each sex (Bick & Sharman 1975). Like most mammals, males have an XY sex chromosome pair, and females have two X chromosomes. *Tachyglossus*, the more widespread genus of echidna, is the only monotreme for which G-banding has been published (Murtagh 1977). There are 63 chromosomes in the male, which has one Y and two X chromosomes (X_1X_2Y). The female has two pairs of X chromosomes ($X_1X_1X_2X_2$) with 64 chromosomes in all. *Zaglossus*, the other genus of echidna, apparently has the same system. Unlike most other mammals, all of the monotreme species studied have unpaired elements at meiosis, which participate in a chain multiple with the sex chromosomes. The three genera of monotremes are karyotypically more similar to each other than to any other mammal.

Marsupials

The marsupials are of special interest because of their unusual characteristics and biogeographic distribution. Chromosome numbers for over 100 species of marsupials are listed by Hayman (1977), and trends analyzed. The chromosome numbers range from 10 to 32, with 14 being the most frequent number, and 22 the next most frequent. The greatest diversity of chromosome number is among the Macropodidae (kangaroos etc.).

Comparing Australian and American marsupials. The relationship of Australian marsupials to those from South America is a question of continuing interest. An important interfamilial comparison of G-banding by Rofe & Hayman (1985) may shed some light on the question. The study included one American species and 14 Australian species, representing four or five superfamilies (depending on the classification scheme). All species had 14 chromosomes, and their banding patterns showed remarkable agreement. These results were interpreted by the author as supporting the common ancestry of both Australian and American marsupials, with the ancestral karyotype being most like the one shared by a wombat (*Vombatus ursinus*), a dormouse possum (*Cercartetus concinnus*), and a bandicoot (*Isoodon obesulus*). Differences between species can be accounted for on the basis of *pericentric inversions* (an inversion including the centromere) and small variations in heterochromatin. The presumed increase in 2n number from the proposed ancestral number of 14 to as many as 32 is attributed to chromosomal fission.

The South American marsupial *Dromiciops* has sometimes been placed in a family separate from other living species. Its chromosomes have not been G-banded, but they appear to be similar to those of the presumed ancestral marsupial 2n=14 karyotype (see Sharman 1982). Karyotypic similarities have also been reported among several species of American opossums (Yonenaga-Yassuda et al. 1982; Casartelli, Rogatto & Ferrari 1986), and among several species of Australian dasyurid marsupials (Young et al. 1982, Baverstock et al. 1983b, Rofe & Hayman 1985).

Kangaroos. The chromosomes of kangaroos and their allies appear to be distinct from those of other marsupials. Rofe (1976) compared the G-bands of ten species of kangaroos and their allies, with 2n ranging from 10 to 22. Numerous chromosome arm homeologies could be identified, suggesting *Robertsonian fusion* (fusion of two chromosomes by their centromeres) to be the predominant type of chromosome rearrangement. The karyotype of the red-bellied pademelon (*Thylogale billardierii*), with 22 chromosomes, was interpreted as being closest to the ancestral condition for the group. Karyotypes for seven species of kangaroos (*Macropus*) were derivable by various fusions. The banding patterns of the swamp wallaby (*Wallabia bicolor*: 10 chromosomes in males, 11 in females) and the rock wallaby (*Petrogale penicillata*: 22 chromosomes, but a different karyotype) displayed greater divergence from the presumed ancestral state. Pericentric inversions and centric shifts (change in position of the centromere) were proposed to explain the differences.

Insectivores

One of the first examples of chromosomal polymorphism to be discovered was the European shrew superspecies, *Sorex araneus*. At least 12 chromosomal forms have been described (see Seale 1984). Differences can be explained on the basis of Robertsonian fusions involving different acrocentrics of an ancestral karyotype. Chromosome numbers range from 20 to 32. Some hybridization occurs, but partial reproductive isolation exists between some of the races. An X-autosome fusion, giving rise to a sex chromosome system of XX in females and XY_1Y_2 in males, is found in some, but not all of the races (Olert & Schmid 1978).

Bats

Bats comprise the second-most-diverse order of mammals. Two suborders are present, the Old World fruit bats and the rest of the bats. Eight species of African fruit bats, representing eight genera, were compared on the basis of their G-bands (Haiduk et al. 1981). In spite of the fact that chromosome numbers ranged only from 34 to 36, substantial differences in banding patterns were detected, requiring at least 34 rearrangements to explain the differences among the eight species. The mechanism for nearly half the rearrangements could not be conclusively identified. This study illustrates that significant karyotypic differences may exist between karyotypes which appear similar superficially.

Most G-banding studies of bats are concerned with the insectivorous and nectar-feeding bats. Patton & Baker (1978) concluded that the ancestral karyotype for the largely tropical American superfamily Phyllostomoidea is most like that of the big-eared bat (*Macrotus waterhousii*). In two different genera, a comparison of banding patterns of two similar species suggested that a total rearrangement of the genome had occurred in one species but not in the other. Another interesting discovery in this study was that the fisherman bat (*Noctilio*), placed in its own family on morphological grounds, has very similar G-banding to that of the mustache bat (*Pteronotus pamellii*), family Mormoopidae. The existence of similar karyotypes in morphologically distinct species and of different karyotypes in morphologically similar species can be interpreted as evidence against the theory that chromosomal rearrangements promote speciation by disruption of genes which regulate development (e.g., Wilson, Sarich & Maxson 1974).

Other good studies of chromosomal banding in bats include those of Haiduk & Baker (1982) on the long-tongued bats (Glossophaginae) and on evening bats by Bickham (1979a,b) and Zima (1982). A summary of the kinds of chromosomal rearrangements proposed in various studies of New World bats was published by Baker & Bickham (1980).

PRIMATES

Because of the great interest in their relationship to humans, primates have been the object of special attention in comparative karyology.

Numerous banding homeologies have been claimed for some 60 species of primates, including man (Dutrillaux et al. 1978). They conclude that "it is likely that all the euchromatin [genetically active chromatin] ... is identical in all the species". This statement, if true, would appear to reduce the significance of chromosomal banding comparisons.

As is often the case, different types of chromosomal rearrangements are typical of different taxonomic groups (*karyotypic orthoselection*; White 1973). In most lemurs Robertsonian rearrangements are the most common type of rearrangement, except for one genus in which tandem fusions are common (Rumpler & Dutrillaux 1976, 1978, 1979; Rumpler et al. 1983b, 1985). If their karyotypes are derived from the presumed ancestral karyotype for the group, Robertsonian rearrangements predominate in the species of *Galago*, while pericentric inversions are more important in *Perodicticus*, a loris (Dutrillaux et al. 1982, Rumpler et al. 1983a). Chromosome fissions are reportedly very frequent in the Old World monkeys, but have not been found in the other families. In the apes pericentric inversions are the most common type of rearrangement.

One of the most variable genera karyotypically is the New World owl monkey, *Aotus*. Nine different karyotypes have been reported, differing by fissions, fusions, and inversions (Ma 1981, Galbreath 1983). The number of sex chromosomes differs among the races. An ancestral karyotype for platyrrhine (New World) monkeys was proposed by Dutrillaux & Couturier (1981). A bibliography of cytogenetic studies in New World primates is available (Mudry de Pargament, Brieux de Salum & Colillas 1984).

Different workers have sometimes obtained different results from study of the same material. This can be illustrated in studies comparing the banding patterns of the grivet (*Cercopithecus aethiops*) and the rhesus monkey (*Macaca mulatta*). One pair of investigators (Stock & Hsu 1973) reported complete matching of the *euchromatin* (genetically active chromatin), with differences explainable as the result of heterochromatin additions or fusions. Another group of investigators (Estop, Garver & Pearson 1978) were unable to match some of the chromosomes in the two species. The claim of nearly complete homeology of banding among the Old World monkeys (Dutrillaux 1979, Dutrillaux et al. 1978) has been questioned by Ponsa et al. (1981), who suggest that the extent of banding homeologies among the primates may have been overstated. They emphasize the need to base homeologies on characteristic banding patterns, not merely short segments, and criticize the construction of karyotypes of hypothetical ancestors as "paper cytology."

Apes and humans. The chromosomes of the great apes have received a great deal of study, and detailed banding patterns have been published and compared with human banding patterns (Yunis & Prakesh 1982). The similarities between chimpanzee and human chromosomes are very striking. Only ten of the 23 pairs of human chromosomes show banding differences when compared with chimpanzee chromosomes. The banding patterns of nine chromosomes are identical in humans and gorillas. The three species differ in their banding patterns by various inversions and a Robertsonian fusion. The fusion involves chimpanzee chromosomes 12 and 13 as equivalent to human chromosome 2 (see Sun, Sun & Ho 1978a,b). No differences in the gene maps of humans and chimps have yet been noted (Lalley & McKusick 1985). In contrast to the usual phylogeny proposed for the group, it is the human karyotype that is considered to be closest to the ancestral type (Yunis & Prakesh 1982). The karyotypes of chimps and gorillas are more similar to the human karyotype than to that of the orangutan.

Carnivores

Banding similarities among the cat, raccoon and mongoose families were reported by Wurster-Hill & Gray (1975). More recently, attempts have been made to propose an ancestral karyotype for the order Carnivora (Dutrillaux & Couturier 1983, Couturier et al. 1986). This hypothetical karyotype is quite similar to that of the palm civet (*Paradoxurus hermaphroditus*, family Viverridae). Seal karyotypes show banding similarities with those of the carnivore families, but bears and dogs have karyotypes that are quite different.

The hypothetical ancestral carnivore karyotype (see above paragraph) was compared with the hypothetical ancestral karyotype previously proposed for the New World monkeys (Dutrillaux & Couturier 1981), prosimian primates (Rumpler et al. 1983b) and the squirrels (Petit et al. 1984, cited by Couturier et al. 1986). Although banding homeologies are claimed for significant portions of the karyotype, the method used has been criticized (Ponsa et al. 1981). Dutrillaux & Couturier invoke gene mapping similarities to support their view of actual homology of the chromosomes.

Karyotypically, one of the most homogeneous families known is the cat family (Wurster-Hill & Gray 1973). Mongooses show significant but varying degrees of similarity with cats (Wurster-Hill & Gray 1975). Translocations involving a sex chromosome are known in at least two genera of mongooses (Pathak & Stock 1976, Fredga 1972).

Seals and Their Allies

There are three families of pinnipeds: true (earless) seals, sea lions (eared seals), and the walrus. These families all share considerable banding homeology, with only four different karyotypes known (Arnason 1977). Differences among the karyotypes were not described thoroughly, but at least one fusion is involved. A striking resemblance to certain carnivore karyotypes was reported, especially to the coati mundi karyotype, but it is not clear whether this similarity was based on banding patterns.

Whales

Whales are generally divided into two major groups, toothed whales (Odontoceti) and baleen whales (Mysticeti). Karyotypes of members of both groups are very similar (Arnason 1974, Arnason et al. 1977), except for the sperm whales, which have distinctive karyotypes. Several species have interstitial heterochromatin and similar C-bands. Some homeologies were reported, but differences have not been described.

Odd-toed Ungulates

Horses are the only members of this order for which I have seen comparative G-banding studies. All seven living species of the horse family have been studied (Ryder, Epel & Benirschke 1978). Each species has a different 2n number, ranging from 32 to 66. Only the X chromosome and a single autosome show the same banding pattern in each species. The other chromosomes all show differences, most commonly involving Robertsonian fusions and pericentric inversions. The mechanism for many of the rearrangements is unknown. The two species of horses have similar chromosomal banding patterns, as do the two species of asses. Two of the three species of zebras have similar patterns, but the pattern in Hartman's zebra is so different that little homeology can be determined in comparisons with the other species.

Even-toed Ungulates

Interfamilial G-band homeologies have been identified (Buckland & Evans 1978) among the cow family (Bovidae), deer family (Cervidae) and the giraffe family (Giraffidae). A hypothesis of chromosomal evolution involving fission has been outlined by Todd (1975) for the order, but our knowledge of this group is still very incomplete.

Camels. Camels have a disjunct distribution, with four species in South America and two species in the Old World. A study comparing banding patterns in two South American species and the Bactrian camel found the G-banding patterns to be indistinguishable (Bunch, Foote &

Maciulis 1985). The distributions of heterochromatin were also indistinguishable, a rather unusual result. The lack of chromosomal divergence despite the geographical isolation is unexpected, and suggests either a very stable karyotype or a relatively short period of isolation, or both.

Cattle family. The karyotypes of the various species of sheep and goats are very similar, with differences attributed to fusions (Bunch, Foote & Spillett 1976). Cattle chromosomes show large homeologies with those of sheep and goats (Schnedl & Czaker 1974). Buckland & Evans (1978), using the goat karyotype as a standard, found nearly complete agreement in banding patterns among several species of bovids, representing three subfamilies. The goat and the horse-like antelope karyotypes were more similar to each other than either was to the cattle karyotype.

A rearrangement which is shared by several similar species is considered to be a good indicator of common ancestry (Rofe 1976). A Y/autosome translocation is found in several species of African cattle-like antelopes (Benirschke et al. 1980), including the eland and the bongo. Differences among the species appear largely due to Robertsonian fusions, with a few tandem fusions and some other unidentified rearrangements. An X/autosome tandem fusion is found in several species of gazelles (Effron et al. 1976, Benirschke et al. 1984). These examples illustrate variability in species which has probably come about relatively recently.

Deer family. One of the most unusual examples of chromosome modification yet discovered is found in the muntjacs, a group of small Asian deer. Two species, the Indian muntjac, *Muntiacus muntjak vaginalis*, and *M. rooseveltorum*, share the distinction of having the lowest 2n number known among mammals, six in the female and 7 in the male (Wurster-Hill & Seidel 1985). The Chinese muntjac, *M. reevesi*, looks very similar but has 2n=46 in both sexes. A comparison of the chromosomes of the Indian and Chinese species (Liming, Yingying & Xingsheng 1980) suggests that essentially the same genetic material is present in each and that the lower number of chromosomes is probably derived by tandem fusion from the 2n=46 karyotype. A fourth species, *M. feae*, has 2n=13 (Soma et al. 1983). Karyotypes of these species illustrate the usefulness of G-banding in comparing karyotypes and show that caution is in order in drawing phylogenetic conclusions based solely on chromosomal data.

Lagomorphs

Species from both the pika family (Ochotonidae) and the rabbits and hares (family Leporidae) have been studied. The two families appear to share very little or no detectable banding homeologies (Stock 1976), but extensive chromosomal similarities are present among the leporids. Hares

(*Lepus*) have similar karyotypes, while cottontails (*Sylvilagus*) show considerable variation (Robinson, Elder & Chapman 1983a,b, 1984). The ancestral karyotype for the group appears to be like that of the hares. Other genera of rabbits appear to be related karyotypically to the hares (Robinson & Skinner 1983, Robinson 1980, Stock 1976). Many of the differences can be ascribed to Robertsonian rearrangements.

Rodents

This is the most diverse order of mammals, and a great amount of cytogenetic study has been done with rodents. However, much more remains to be done. Most comparative studies of rodent G-banding have been done with rats and mice, and many families have not yet been studied. A recent bibliography of rodent karyological studies is available (Jotterand-Bellomo 1984).

The G-banding patterns of thirteen species of ground squirrels (*Spermophilus*) have been published (Nadler et al. 1973, 1975, 1984), and extensive homeologies determined. An interesting geographical pattern has been discovered in this group. The arctic ground squirrel, *S. parryi*, is found on both sides of the Bering Strait, both populations having identical karyotypes. The arctic ground squirrel populations separate two other species: *S. columbianus* in North America and *S. undulatus* in Siberia. The banding patterns of these two species are identical. The highest 2n numbers in the genus are found in the Asian *S. xanthoprymnus* (2n=42) and the North American *S. vigilis* (2n=46). These two species differ primarily by two fusions. In contrast to the karyotypic variability of the squirrel genus *Spermophilus*, most chipmunks (genus *Tamias*), have very similar karyotypes (Nadler et al. 1977).

By far the largest family of mammals is the mouse family, and a large number of chromosomal studies have been conducted among its members. Only a few studies can be described here. All species of white-footed mice (*Peromyscus*) studied so far have 48 chromosomes (Robbins & Baker 1981). The most primitive karyotype was proposed to be that of *P. boylii*. A modified *Peromyscus* karyotype was proposed to be ancestral for the family by Koop et al. (1984). They noted that karyotypic differences may be more extensive among species in a genus than between genera.

One of the most interesting cases of chromosomal speciation is found in the house mouse (*Mus musculus* complex). Chromosome numbers range from 22 to 40, with differences due to Robertsonian rearrangements (Gropp & Winking 1981). Such a situation is called a “Robertsonian fan”. Several other species from the same subgenus share identical banding patterns with *Mus musculus*, but at least some species in other subgenera have quite different banding patterns (Hsu, Markvong & Marshall 1978). Another Robertsonian fan has been described in the European mole-vole, *Ellobius talpinus* (Lyapunova et al. 1984). Here the 2n number varies from 31 to 54 within a geographic distance of only 150 km. All chromosome numbers from 31 to 54 have been found, indicating extensive introgression.

Several genera of native Australian rodents, representing three tribes, have been studied. Each of the three tribes contains a species with a common banding pattern (Baverstock et al. 1983a). These Australian rats have virtually no banding homeologies with species of *Rattus*, indicating only a distant relationship. One genus (*Zyzomys*) has apparently had its genome completely rearranged.

Banding patterns of ten genera of murid rodents, mostly of African origin, were compared by Viegas-Pequignot et al. (1983), and an ancestral karyotype proposed for the murid rodents. Several examples were noted in which a particular type of rearrangement appears to have accumulated in a particular lineage (karyotypic orthoselection). This ancestral karyotype for murid rodents was compared with that of a South American cricetid, *Akodon arviculoides* to test for similarities between the two subfamilies (Viegas-Pequignot et al. 1985). About 40% homeology was claimed. It would be interesting to compare the “ancestral” karyotype proposed by these authors with that given by Koop et al. (1984).

South American hystricomorph rodents. Several families of mostly South American rodents are included in the hystricomorphous rodents. Not many studies of G-band comparisons have been published, and fewer yet in English. A review of unbanded karyotypes of hystricomorphs was published by George & Weir (1974). Three species of Caviidae, representing three genera, were compared by Maia (1984). Differences reported were primarily due to heterochromatin content. Chromosomal speciation appears to be taking place among populations of a superspecies of spiny rats (*Proechimys*, Family Echimyidae) in Venezuela (Reig et al. 1980). Chromosome numbers range from 42 to 62. Differences are due to Robertsonian fusions, except for the extreme chromosome numbers, where pericentric inversions are also involved.

Miscellaneous rodent families. Five species of gundis (family Ctenodactylidae), representing four genera, have been shown to have similar chromosomal banding patterns (George 1979a). Differences can be explained by a pericentric inversion, and perhaps several very small translocations. The same author (George 1979b) found very close similarity in the banding patterns of two species of African mole-rats (family Bathyergidae). This contrasts sharply with the variability seen in some other families of burrowing rodents and casts doubt on the hypothesis that chromosomal evolution is especially promoted by the kind of social structure found in burrowing rodents (Wilson et al. 1975; see also Gileva 1983).

A CREATIONIST VIEWPOINT

A Challenge for Creationism

Although much remains to be learned about the meaning of chromosomal structure, enough data on chromosomal comparisons have been gathered to raise some important questions for creationists. That changes have occurred in organisms since creation is not in question, but the extent of those changes is uncertain.

Species which are similar morphologically generally have similar karyotypes, although there are significant exceptions (e.g., see Liming, Yingying & Xingsheng 1980). This is quite reasonable if species with similar morphology (e.g., in the same genus) are thought of as being related through common ancestry. The occasional exception merely shows that chromosomes can be extensively rearranged with no significant morphological effect.

More problematic is the finding that species which are quite different morphologically may have similar karyotypes. The chromosomal similarities among many of the Australian marsupials (Rofe & Hayman 1985), between goats and giraffes (Buckland & Evans 1978), between seals and terrestrial carnivores (Arnason 1977) and between humans and the great apes (Yunis & Prakesh 1982) raise some significant questions for creationists. Perhaps the two most important questions are:

1. To what extent has morphological change occurred in mammals, and by what mechanisms? and
2. What is the relationship between humans and apes?

These questions will be amplified below, and then various hypotheses regarding the relationship of chromosomal evidence to these questions will be discussed.

Problem 1. The extent and mechanism of morphological change. There is circumstantial evidence that mammal species may change significantly in their morphology. This evidence comes from the study of island populations (e.g., Lawlor 1982, Simpson 1956), from the results of selective breeding of domestic animals (e.g., Wayne 1986), from the ability of some animals to hybridize (Van Gelder 1977), and from distributional patterns of living mammals (Darwin 1859). However, there seem to be limits on the amount of morphological change possible (Lester & Bohlin 1984).

If groups such as the Australian marsupial families are considered to share a common ancestry in spite of their diverse morphology, one is challenged to propose some mechanism by which such change could be brought about. The standard neodarwinian gradualistic explanation for morphological change is that small changes arise by mutation and accumulate over time by natural selection to produce large changes (e.g., see Charlesworth et al. 1982). However, the lack of fossil intermediates, or even conceivable intermediate stages, has led many scientists to search for other explanations. Several alternative mechanisms for macroevolutionary changes have been proposed (e.g., Gould 1977; Oster & Alberch 1982; Wilson, Maxson & Sarich 1974; Wright 1982), but none has been satisfactory. The possible role of chromosomal rearrangements in speciation was discussed in a previous article (Gibson 1984).

For creationists, the origin of diversity in mammals is an important question. If enough morphological change has occurred since the Genesis flood to explain the origin of diversity among marsupials, it seems reasonable to think that the same amount of change could also have happened among placental mammals, although placentals as a group do not have such similar chromosomal banding patterns as marsupials. However, in the absence of a plausible genetic mechanism for creating new adaptations, creationists are somewhat skeptical that such changes have occurred, even though there is no scriptural prohibition against large changes in species.

If the marsupials are considered to be unrelated, then one has the problem of explaining why they share so many unique characteristics, including chromosomal similarities and such structural traits as their reproductive anatomy, the presence of epipubic bones, and the inflection of the angular process of the lower jaw. Their geographic distribution is also difficult to explain.

Problem 2. The relationship of man and the apes. Questions concerning the origin and nature of man have deep philosophical significance. Evolutionists have long held that humans and apes share a common ancestry, a belief based largely on morphological similarities. Fossil discoveries have not clarified the picture, but seemingly have made it more confused, perhaps due to the subjective nature of interpreting the fossils (Washburn 1973). However, striking similarities have been discovered between apes and humans in their proteins (Bruce & Ayala 1979), their chromosomes (Yunis & Prakesh 1982), and in their DNA (Sibley & Ahlquist 1984).

To say that humans and apes are not related by common descent is to emphasize their difference in anatomy and behavior, and to downgrade the importance of their similarities in anatomy, biochemistry and chromosomes. Although the human karyotype is considered to be closest to the ancestral condition for humans and apes (Yunis & Prakesh 1982), I am not aware of any serious examination of the possibility that humans might be ancestral to apes.

The Meaning of Chromosomal Similarity

As an explanation for similarities in chromosomal structure, four distinct possibilities come to mind, each presented as a separate hypothesis below.

Hypothesis 1. Chromosomal similarities are the result of common design. This would mean that organisms which are similar morphologically were created with similar karyotypes, just as they were created with similar anatomical and biochemical features. If the karyotypes have not undergone much change since creation, we should be able to see the similarities. Whether a karyotype should be shared by all mammals or only by those with some degree of morphological similarities is uncertain.

If a karyotype is shared only by species with similar morphology, one might infer that the structure of the chromosomes is somehow related to the morphology of the organism. It is true that, in general, groups of species with similar G-banding patterns are also similar morphologically. However, it is known that major changes in the karyotype, as shown by G-banding, do not cause morphological change (e.g., see Baker, Bickham & Arnold 1985). It is also known that different types of chromosomal change may be found in groups of species which could plausibly have a common ancestry (e.g., see Koop et al. 1984). These facts cast doubt on any fixed relationship between chromosome morphology and anatomical morphology, although they do not disprove a possible original relationship between them.

There have been some suggestions that karyotypic structure has adaptive significance (Baker et al. 1983, Kiel et al. 1985), but this has not been demonstrated conclusively. It is of interest to note that there is frequently a correlation between anatomical distinctiveness and karyotypic distinctiveness between groups at high taxonomic levels.

Hypothesis 2. Chromosomal similarities are exclusively the result of common ancestry. According to this hypothesis, if two species have similar chromosomes (including banding patterns), they are related. This would require that each original species group was created with its own unique karyotype. If this hypothesis is correct, one must accept a common ancestry for apes and humans, for at least the majority of the marsupials, and for cattle, goats, antelope and giraffes. Acceptance of this hypothesis is the basis for phylogenies based on chromosomal similarities.

There are problems with this hypothesis. One is that despite some circumstantial evidence for major morphological change in mammals, no mechanism is known which would account for the kind of changes here suggested. Among the Australian marsupials, for example, there are considerable morphological differences between the wombat, the bandicoot and the "native cat". A second problem is that in comparing banding patterns which are similar but may not be identical, preconceived ideas of ancestry can bias one's conclusions (e.g., see above under *Primates*). If one assumes that two similar species do in fact have a common ancestor, then one is committed to finding a way of matching the banding patterns. In view of the subjectivity involved in matching chromosomal banding patterns, one might wonder about the significance of a 25% or 50% match of banding patterns, especially it no entire arms can be matched.

Hypothesis 3. Chromosomal similarities are due to random changes which happen to produce the same banding pattern in different species. This hypothesis implies that each originally created species had a unique karyotype. It also implies that chromosomal similarities have no real significance. If a series of patterns is made by randomly arranging dark and light bands, it is inevitable that some patterns will be repeated by chance. Thus the similarities of chromosome banding in humans and apes and within some other groups could be held to be merely a result of chance.

This hypothesis does not seem reasonable for two reasons. Similar chromosome banding patterns are not found randomly distributed throughout all taxonomic groups, but rather are found in groups which share morphological similarities. This argues strongly against any random cause of the banding patterns. In fact, it is known that breakage points in chromosomes are not random (Jacky, Beek & Sutherland 1983), and so changes in a karyotype will not be random. The phenomenon of "karyotypic orthoselection" also shows that chromosomal changes are non-random. If chromosomes have non-random breakage points, similar (parallel) rearrangements could occur independently in similar karyotypes (see below), but it is unlikely that convergent events would occur in different karyotypes to produce similar results.

Hypothesis 4. Chromosomal similarities are the result of non-random changes due to viruses or transposable elements. This hypothesis requires that either 1) karyotypes which were once different have been caused to become similar, or 2) karyotypes which were once similar have been changed in a similar way, due to the action of transposable elements or some similar mechanism.

Transposable elements (TEs) are known to increase the rate of chromosomal rearrangements in a non-random way (Nevers & Saedler

1977). But if the karyotypes were substantially different, there is no reason to expect them to change to be the same, since the insertion sites of TEs appear to be at least partially sequence-dependent (see Inouye, Yuki & Saigo 1984; Shapiro 1979).

Similar (parallel) changes do sometimes occur in similar species, as has been shown in several studies (e.g., Robbins & Baker 1981; Baker, Koop & Haiduk 1983; Baker, Bickham & Arnold 1985; Searle 1984). A common ancestry is plausible in each of these cases, and it is likely that the rather similar species have undergone numerous chromosomal changes during speciation, some of which happened to be the same.

It seems more likely that transposable elements could cause karyotypes which were originally similar to become different. This could occur if different species were infected by different TEs or retroviruses having different effects on the genome (see Rose & Doolittle 1983). It seems possible that different TEs might affect a genome in different ways. As a hypothetical example, it seems possible that the ancestors of oryzomine and peromyscine rodents (groups of rats and mice) could originally have had similar karyotypes when infected by different TEs. The TE(s) infecting the peromyscine lineage might have caused a series of heterochromatin additions and pericentric inversions, while the TE infecting the oryzomine lineage might have caused a series of fusions.

CONCLUSIONS

It is possible that chromosomal similarities have different explanations in different groups of animals. It this is true, then one must be cautious in using chromosomal comparisons to determine relationships. Nevertheless, chromosomal data can serve as a useful check on data from other sources.

Hypothesis 3, that chromosomal similarities are due to random chromosomal rearrangements which happen to produce similar banding patterns, is not reasonable, for reasons discussed above. Hypothesis 2, that chromosomal similarities are exclusively the result of common ancestry, does not seem consistent with creation theory and does not seem a necessary conclusion from the scientific data. The fact that very large genomic rearrangement does not seem to affect morphology, and yet animals with different body plans (“Bauplan”) appear to have very different kinds of karyotypes suggests to this writer that some different groups had different starting points and do not share a common ancestry.

Hypotheses 1 and 4 seem consistent with both creation theory and the evidence available. It seems likely that species which were morphologically similar were created with similar chromosomes, reflecting their genetic similarity. It is evident that large changes have occurred in chromosomes since creation. These changes have often resulted in karyotypic divergence and have contributed to the multiplication of species.

Chromosomal rearrangements seem to occur so frequently that one would expect to find very little banding homeology between species which supposedly diverged long ages ago, such as the marsupials. The existence of numerous banding homeologies can be explained as the result of a common design which has been preserved only because a relatively short time has been available for changes to occur.

How much anatomical change has occurred since creation is still an unanswered question. Chromosomal comparisons suggest that new genera may have arisen since creation, for example among the antelopes which share a Y/autosome translocation (Benirschke et al. 1980). Whether larger changes have occurred cannot be determined from chromosomal studies. At the present time there is no known mechanism by which changes in organisms can take place which are large enough to account for the differences among, for example, the Australian marsupials or the various families of artiodactyls (cattle, giraffes, deer). The absence of fossil evidence linking different groups by a common ancestry, together with the lack of biological evidence of a mechanism for such change, seem consistent with the hypothesis that they have separate ancestries.

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NEWS AND COMMENTS

LOUISIANA CREATIONISTS APPEAL TO THE U.S. SUPREME COURT

Although the Louisiana Act for Balanced Treatment of Creation-Science and Evolution-Science received a setback by an appeals court, its supporters have been granted a full review by the U.S. Supreme Court.

On July 8, 1985, a three-judge panel of the U.S. Fifth Circuit Court of Appeals upheld the earlier summary judgment against the Balanced Treatment Act by Federal Judge Adrian Duplantier (see *Origins* 12:39-40). The appeals court ruled that “irrespective of whether it is fully supported by scientific evidence, the theory of creation is a religious belief” and that “the act’s intended effect is to discredit evolution by counterbalancing its teaching at every turn with the teaching of creationism, a religious belief.” The court concluded that the act thereby violated the constitutional principle of separation of church and state.

State Attorney General William J. Guste, Jr., immediately petitioned for a rehearing by the full Court of Appeals, and Bill Keith, president of the Creation Science Legal Defense Fund, expressed the expectation that “we have succeeded in reversing summary judgment once, and we expect to succeed again.”

On December 12, 1985, by a narrow margin of 8-7, the Court of Appeals denied rehearing *en banc*. Speaking for the seven dissenting judges, Judge Thomas Gibbs Gee issued a strongly worded, 5-page opinion repudiating the majority ruling: “The statute ... has no direct religious reference whatever and ... requires no more than that neither theory about the origins of life and matter be misrepresented as fact.” Presentation of both views would ensure “that within the reasonable limits of the curriculum, the subject of origins will be discussed in a balanced manner if it is discussed at all.” Gee also observed that “I am surprised to learn that a state cannot forbid the teaching of half-truths in its public schools, whatever its motive for doing so.... It comes as news to me ... that the Constitution forbids a state to require the teaching of truth — any truth, for any purpose, and whatever the effect of teaching it may be.”

On December 16, Attorney General Guste announced that he would appeal to the U.S. Supreme Court for an overrule of the summary judgment by Duplantier. In a letter to the New Orleans *Times-Picayune*, he explained:

> *The dissent by Judge Thomas Gibbs Gee is an intellectual tour de force that is a ringing endorsement of the concept of federalism. That concept holds that federal courts will not declare state law unconstitutional unless they patently violate the United States Constitution.*
>
> *The dissent made the clear point that the law on its face in no way expressed a religious purpose. On the contrary, it defines a secular purpose, namely to ensure academic freedom.*

Martha Kegal, Louisiana ACLU Executive Director, criticized Guste's decision:

> *Given everyone's concern about deficient public education and a tight state budget, Louisiana cannot afford to waste several million dollars in defense of an obviously unconstitutional law that weakens science instruction.*

On May 5, the U.S. Supreme Court agreed to give full review to the case. Oral argument is expected late this year. If the U.S. Supreme Court overrules the summary judgment, supporters of the statute will return to the federal court in New Orleans for rehearing.

Katherine Ching

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

THE GREAT TWENTIETH-CENTURY MYTH

EVOLUTION: A THEORY IN CRISIS. 1985. Michael Denton. London: Burnett Books, The Hutchinson Publishing Group. 368 p.

Reviewed by R.H. Brown, Geoscience Research Institute

Among the recent spate of books dealing with evolution/creation issues, *Evolution: A Theory in Crisis* is unique. The author is a Ph.D. molecular biologist who is active in research at the Prince of Wales Hospital in New South Wales, Australia. The book is of the sort that interested readers will want to underline, annotate, and retain for frequent future reference.

Many readers will eagerly press on, if not look ahead, to discover what explanation Dr. Denton offers for the origin of life after demolishing Darwinism. He offers no alternative and lightly dismisses creationism as an ancient myth. His book is an honest and competent effort to let the facts fall where they may. His sympathetic treatment of Charles Darwin will increase the respect of many readers for Darwin as a man and as a scientist. The early chapters display a lucid style that provides delightful reading. In succeeding chapters, as technical and philosophical depth increases, there is a tendency for sentences sometimes to become highly involved and difficult to understand. Typographical errors appear more frequently than is normally expected in publications of the quality represented by this book. Occasionally these errors interfere with reader comprehension (e.g., 100 in place of 10 in line 4 on p 312). In the hope of stimulating a wider readership of this book, I will offer some chapter-by-chapter comments and selections.

Chapter 1 provides a valuable historical summary of the transition from a literalist biblical view of the natural world to the Darwinian view.

Chapter 2 traces materialistic evolutionary concepts back to the early Greeks and outlines the development of Charles Darwin's concept of evolution by random variation coupled with natural selection. Discussing the social impact of Darwinism, Denton says:

> *Despite the attempt by liberal theology to disguise the point, the fact is that no biblically derived religion can really be*

> *compromised with the fundamental assertion of Darwinian theory* (p 66).
>
> *It was because Darwinian theory broke man's link with God and set him adrift in a cosmos without purpose or end that its impact was so fundamenta. No other intellectual revolution in modern times ... so profoundly affected the way men viewed themselves and their place in the universe* (p 67).

Chapter 3 traces the phenomenal success of Darwinism as a development from highly speculative hypothesis to dogma within 20 years after the first publication of *The Origin of Species* in 1859. The author points out that "Once a theory has become petrified into a metaphysical dogma it always holds enormous explanatory power for the community of belief" (p 76).

Reviewing the evidence for the development of new species by natural selection (special theory of evolution) (chapter 4), Denton observes that:

> *The validation of Darwin's special theory, which has been one of the major achievements of twentieth-century biology, has inevitably had the effect of enormously enhancing the credibility of his general theory of evolution* (p 86).

However,

> *The German zoologist, Bernhard Rensch [1959], was able to provide a long list of leading authorities who have been inclined to the view that macroevolution cannot be explained in terms of microevolutionary processes, or any other currently known mechanisms. These dissenters cannot be dismissed as cranks, creationists, or vitalists, for among their ranks are many first-rate biologists* (p 86).

The contrast between classical typology and the evolutionary concept is elaborated in chapter 5:

> *The fact that so many of the founders of modern biology, those who discovered all the basic facts of comparative morphology upon which modern evolutionary biology is based, held nature to be fundamentally a discontinuum of isolated and unique types unbridged by transitional varieties, a position absolutely at odds with evolutionary [sic] ideas, is obviously very difficult to reconcile with the popular notion that all the facts of biology irrefutably support an evolutionary interpretation* (p 100).

The presumption that for these scientists the "typological model of nature was derived not from the facts of nature but from religious and metaphysical preconceptions ... has persisted as one of the great myths of twentieth-century biology" (p 100). Further,

> *... in the seventeenth and eighteenth centuries, many biologists and philosophers, influenced by the doctrine of the plentitude of creation and its corollary, the concept of the great chain of being, saw in theology a demand for continuity just as absolute as that demanded by modern evolutionary biology* (p 101).

In chapter 6 the author reviews biological classification (the *Systema Naturae*) from Aristotle to modern cladistics. His viewpoint is expressed in the following quotation:

> *The fact that all the individual species must be stationed at the extreme periphery of ... logic trees merely emphasized the fact that the order of nature betrays no hint of natural evolutionary sequential arrangements, revealing species to be related as sisters or cousins but never as ancestors and descendents as is required by evolution* (p 132).

According to chapter 7, from Darwin's time up to the present, homology has been the mainstay of the argument for evolution. "Without the phenomenon of homology — the modification of similar structures to different ends — there would be little need for a theory of descent with modification" (p 154). Denton points out that homologous organs and structures may develop by radically different embryogenic routes, and that "the evolutionary basis of homology is perhaps even more severely damaged by the discovery that apparently homologous structures are specified by quite different genes in different species" (p 149).

Chapter 8 discusses what the author considers the major flaw in the argument for macroevolution, the lack of intermediate forms, and contains a detailed discussion of the few fossils that have been claimed to be transitional forms. The adequacy of the fossil record for conclusive evidence is supported by the observation that 79.1% of the living families of terrestrial vertebrates have been found as fossils (87.8% if birds are excluded).

Chapter 9 is devoted to the possibility of hypothetical evolutionary pathways across the gaps that are the subject of the preceding chapter. Denton affirms that:

> *Evolution by natural selection would be established today beyond any reasonable doubt, even without empirical evidence of intermediates, if it had been shown that all the great divisions of nature could at least theoretically have been crossed by inventing a really convincing series of hypothetical*

> *and fully functional transitional forms. However ... this has never been achieved* (p 200-201).

He then provides an impressive collection of Wonders of Nature — examples of both structure and behavior that could not be bridged by any conceivable series of transitional steps. He elaborates on the hypothetical evolution of reptilian scales into avian flight feathers, the basic vertebrate "in and out" flow type of lung into the avian unidirectional flow lung, and of the amphibian egg into the amniotic egg.

After an introduction to molecular biology in chapter 10, Dr. Denton proceeds in chapter 11 to a discussion of the chemical evolution necessary for a naturalistic origin of life. In his opinion, "the existence of a definite discontinuity" between life and the inorganic world "was only finally established after the revolutionary discoveries of molecular biology in the early 1950s" (p 249). He affirms that there is absolutely no positive evidence for the existence of the "prebiotic soup" in which life presumably originated (p 261), and that "the most difficult aspect of the origin of life problem lies not in the origin of the soup but in the stages leading from the soup to the cell" (p 263). If the primeval atmosphere had contained oxygen, any organic molecules that might have developed would have been destroyed by oxidation. If the primeval atmosphere did not contain oxygen, there would have been no ozone screen to prevent ultraviolet radiation from destroying any organic molecules that might have formed.

Chapter 12 contains what is probably the most significant contribution of this book to the literature on evolution: the author's insights on comparative biochemistry. Rather than seeing biochemical similarities (e.g., between man and ape) as evidence for an evolutionary ancestry, he sees biochemical differences as one of the strongest categories of evidence against Darwinian evolution:

> *It is now well established that the pattern of diversity at a molecular level conforms to a highly ordered hierarchic system. Each class at a molecular level is unique, isolated and unlinked by intermediates. Thus molecules, like fossils*[,] *have failed to provide the elusive intermediates long sought by evolutionary biology.... At a molecular level, no organism is 'ancestral' or 'primitive' or 'advanced' compared with its relatives* (p 290).

Regarding the biochemical data,. Dr. Denton affirms that evidence for evolution is only such when viewed with the eye of faith (p 292).

Regarding the molecular clock hypothesis, according to which a constant rate of mutation is presumed to provide a time interval between the appearance of two sequentially related genes, Dr. Denton concludes that:

> *Rather than being a true explanation, the hypothesis of the molecular clock is really a tautology, no more than a restatement of the fact that at a molecular level the representatives of any one class are equally isolated from the representatives of another class* (p 296).

Chapter 12 is entitled "A Biochemical Echo of Typology" and concludes with this paragraph:

> *What has been revealed as a result of the sequential comparisons of homologous proteins is an order as emphatic as that of the periodic table. Yet in the face of this extraordinary discovery the biological community seems content to offer explanations which are no more than apologetic tautologies* (p 306).

Many readers will wish that some portions of this chapter had been written with greater clarity and more detailed explanation.

In chapter 13 Dr. Denton gives a fresh approach to the probability for random evolution of a functioning protein. From a comparison with complex computer programs he says:

> *The fact that systems in every way analogous to living organisms cannot undergo evolution by pure trial and error and that their functional distribution invariably conforms to an improbable discontinuum comes, in my opinion, very close to a formal disproof of the whole Darwinian paradigm of nature* (p 315-316).

The apparent design at the molecular level of the biotic world is developed further in chapter 14. According to one of the striking illustrations given in this chapter, if one atom representation were put in place every minute, 50 million years would be required to construct an exact model of a typical cell. If the model were to a scale on which each atom would be the size of a tennis ball, the complete model would have a diameter of about 20 kilometers. Probability models as often used against evolution are fraught with problems, especially when exact figures are sought. Yet there is little doubt that mathematical probability estimates are a major problem for naturalistic evolution.

The following representative excerpts are taken from the final chapter:

> *Since 1859, a vast amount of evidence has accumulated which has thoroughly substantiated Darwin's views as far as*

> *microevolutionary phenomena are concerned.... it is beyond any reasonable doubt that new reproductively isolated populations — species — do in fact arise from pre-existing species* (p 344).
>
> *The very success of the Darwinian model at a micro-evolutionary level ... only serves to highlight its failure at a macroevolutionary level.*
>
> *Neither of the two fundamental axioms of Darwin's macroevolutionary theory — the concept of the continuity of nature, that is[,] the idea of a functional continuum of all life forms linking all species together and ultimately leading back to a primeval cell, and the belief that all the adaptive design of life has resulted from a blind random process — have been validated by one single empirical discovery or scientific advance since 1859* (p 344-345).
>
> *The cultural importance of evolution theory is... immeasurable, forming as it does the centerpiece, the crowning achievement, of the naturalistic view of the world, the final triumph of the secular thesis which since the end of the middle ages has displaced the old naive cosmology of Genesis from the western mind* (p 357-358).
>
> *Ultimately the Darwinian theory of evolution is no more nor less than the great cosmogenic myth of the twentieth century* (p 358).

Not all scientists will accept Dr. Denton's principal conclusions. Some will disagree here and there with a detail of interpretation on which his conclusions are based. But everyone, evolutionist or creationist, who is concerned with the scientific witness concerning the origin of life should be familiar with the content of his book.

ANNOTATIONS FROM THE LITERATURE

Bowler PJ. 1983. The eclipse of Darwinism. Anti-Darwinian evolution theories in the decades around 1900. Baltimore & London: The Johns Hopkins University Press. 291 p.

> ***Summary.*** Covers comprehensively the previously barely studied period around the turn of the 20th century where the reactions and counter-reactions to Darwin were more severe than the current debates over evolution and creation. The author takes the reader through the initial period of theistic evolution to the synthesis of Darwinism with genetics which culminated in the mutation theory.

Branscomb LM. 1985. Integrity in science. American Scientist 73:421-423.

> ***Summary.*** This is a must for anyone interested in the question of the validity of science. The author, chief scientist for IBM, points out that there is very little malice in science, but a great deal of self-deception. Scientists, instead of probing thoroughly through the harder questions of their queries, cease when their data agree with expected results.

Brooks DR, Wiley EO. 1986. Evolution as entropy. Toward a unified theory of biology. Chicago & London: University of Chicago Press. 335 p.

> ***Summary.*** An attempt to reconcile the second law of thermodynamics, which predicts disorder with time, with biological evolution, which predicts increase in organization with time.
>
> ***Comment.*** This book should be read by anyone interested in learning how to argue that black is white, or left is right, etc.

The Decade of North American Geology (DNAG) Series. Publishing dates 1985-1988. Approximately $30/volume. Boulder, CO: Geological Society of America.

> ***Summary.*** The DNAG releases comprise a series of 40 well-illustrated volumes which include: the United States (17 vols.), Mexico (2 vols.), Canada (9 vols.), field guides (6 vols.), special topics (4 vols.), 23 continent-ocean transects, and 7 spread maps of North America. Produced and edited by over 1000 collaborators, the series promises to be a landmark reference on North American geology.

Eyles N, editor. 1983. Glacial geology. An introduction for engineers and earth scientists. NY: Pergamon Press. 409 p.

Summary. This multi-authored volume deals with both theoretical considerations and practical consequences of glaciation. It is unusual in that it raises serious questions regarding some traditional interpretations of glacialogy.

Gale BG. 1982. Evolution without evidence. Charles Darwin and *The Origin of Species*. Albuquerque: University of New Mexico Press. 238 p.

Summary. A study of Charles Darwin's work from 1838 to the time of the publication of *The Origin of Species* in 1859. The author points out the weaknesses in Darwin's argumentation which relied heavily on the work of others. Factors contributing to the success of Darwinism are also considered. A well-documented study.

Hallam A. 1983. Great geological controversies. NY: Oxford University Press. 182 p.

Summary. A brief and well-documented account of the major geological battles that were waged as this science matured. Controversies considered include neptunists-plutonists, catastrophism and uniformitarianism, the ice age, the age of the earth, and continental drift.

Mahaney WC, editor. 1984. Quaternary dating methods. Developments in Palaeontology and Stratigraphy, 7. Amsterdam: Elsevier Science Publishers. 431 p.

Summary. A discussion of a wide variety of methods used for dating the Quaternary. Most of the papers candidly evaluate the limitations of the methods employed and the implied inferences.

Comment. This volume is a must for anyone wanting to evaluate current dating techniques.

Rutter NW, editor. 1985. Dating methods of Pleistocene deposits and their problems. Geoscience Canada, Reprint Series 2. Geological Association of Canada. 87 p.

Summary. This concise volume covers over a dozen different methods for dating recent samples. It is written in a readily understandable style. Several of the methods are interdependent, and consideration is given to the problems encountered with each method.

Seibold E, Meulenkamp JD. 1984. Stratigraphy quo vadis? American Association of Petroleum Geologists Studies in Geology No. 16, International Union of Geological Sciences No. 14. 70 p.

Summary. The report of a symposium of the Commission on Stratigraphy of the International Union of Geological Sciences. Held in Germany, the symposium was attended by 60 geologists from 13 countries. It was organized to incorporate the new data for the oceanic realm that have been obtained especially from the Deep-Sea Drilling Project and related programs. The report presents the summary of 11 papers and reflects the tendency towards episodicity and cyclicity of events in contrast to more gradual and sustained changes proposed a few years ago. While major conclusions are not arrived at, this summary serves to indicate potential new trends in stratigraphy.

Shapiro R. 1986. Origins: a skeptic's guide to the creation of life on earth. NY: Summit Books. 332 p.

Summary. A witty, easy-to-read evaluation of a variety of concepts of the origin of life, including origin in a primordial soup, clay, space, and by creation.

Comment. The author is somewhat critical of all commonly held views, but disappointingly does not come up with anything better. The book is well-written and entertaining, but does not provide any new ideas regarding origins.

Takahashi K, Mathews GJ, Bloom SD. 1986. Shell-model calculations of ^{99}Tc beta decay in astrophysical environments. Physical Review C 33(1):296-302.

Summary. The purpose of this paper was to recalculate the half life of ^{99}Tc (Technetium) in astrophysical environments. Previous calculations at 3×10^8 ºK gave a decay half life of about 5 years. This is shorter than the 10-100 year time scale usually suggested for formation. According to theory, then, no ^{99}Tc would be expected at the stellar surface. In fact, it is abundant on at least some red-giant starts. The half-life calculated in this paper is 20 years instead of 5 years, removing the contradiction between theory and observation.

There is general agreement between this and previous papers in that, whether the half life of ^{99}Tc is 5 or 20 years at 3×10^8 ºK, it is still 5 orders of magnitude shorter than the half life of 2.12×10^5 years observed at terrestrial temperatures. Theory gives the following order of magnitude half lives as temperature increases: 0 ºK — 2×10^5 years; 1×10^8 ºK — 2×10^5 years; 2×10^8 ºK — 100 years; 3×10^8 ºK — 10 years;

5×10^8 °K — 1 year. (For comparison the sun's surface temperature is 6000 °K.) The decay rate changes because at high temperatures the ^{99}Tc neutrons gain energy and are promoted from the ground state into several excited states. The spin of the ground state is such that beta decay to ^{99}Ru is forbidden by selection rules. As a result this decay rate is slow. The spins of two of the excited states are such that beta decay is allowed by the selection rules, and the decay is much faster.

A NEW JOURNAL — AGAIN!

PALAIOS. Bimonthly, $75.00/year. Issue 1, February 1986. Published by the Society of Economic Paleontologists and Mineralogists, a division of the American Association of Petroleum Geologists. SEPM, P.O. Box 4756, Tulsa, OK 74159-0756.

Summary. This journal appears to be a good one. The title is from the Greek "palaios," meaning "ancient," and the journal proposes to cover historical biology, especially where paleontology and biology become significant to geological interpretations. Nominally it covers paleontology, paleobiology, paleogeography, paleoecology, and paleoceanography. The two issues published to date cover topics from sedimentology to contemporary biology, with much emphasis on paleontological subjects. The composition of the journal includes more than a compilation of research reports. Divisions are: Online (editorial), Research Reports, Research Letters, New Books, News and Comments, and Afterthoughts (miscellaneous comments).

This journal accommodates the much-needed interdisciplinary studies that are so important in the study of earth history. It is informal enough to allow some bold suggestions such as molluscan shells carried almost instantly 500 km offshore into the Atlantic Ocean by turbidity currents, and a reef from the near Europe Tethys Sea being rifted to eastern Oregon. Techniques of analysis of data and the study of preservation of organisms further enrich this useful journal.

GENERAL SCIENCE NOTES

RECENT DEBATE OVER *ARCHAEOPTERYX*

By Venus E. Clausen, Geoscience Research Institute

WHAT THIS ARTICLE IS ABOUT

Archaeopteryx *is considered to be an important example of a missing link between two major classes of animals. It has been subjected to much controversy since its discovery over a century ago. Recently, a group of physicists challenged the authenticity of the plumage of* Archaeopteryx. *They suggested that feathers were artificially impressed on a thin layer of cement which was applied to the skeleton of a flying reptile. In response to the challenge, paleontologists from the British Museum (Natural History) conducted a series of tests on the holotype of* Archaeopteryx. *They found no evidence of a cement layer on the fossil. Nevertheless, the history associated with the two best* Archaeopteryx *fossils leaves some unanswered questions concerning their authenticity.*

Since its discovery over a century ago, *Archaeopteryx* has been a subject of much controversy. Because it exhibits both avian and reptilian characteristics, *Archaeopteryx* is usually considered an intermediate form, an important example of a missing link.

In 1983 the authenticity of *Archaeopteryx's* plumage was questioned (Trop 1983). More recently (March-June 1985), the *British Journal of Photography* (BJP) published a series of four articles which resumed the challenge that *Archaeopteryx* was a hoax (Watkins et al. 1985a,b,c; Hoyle et al. 1985). Because of the prominence of some of the authors (e.g., Sir Fred Hoyle, a well-known astrophysicist), this accusation received much attention.

Archaeopteryx, the earliest fossil bird, is represented by six fossils — five skeletons and one feather (see Table 1). All were excavated from the Solnhofen limestone (Upper Jurassic) in the vicinity of Eichstatt, Germany. The first skeleton (holotype of *Archaeopteryx*) was purchased in 1862 by the British Museum (Natural History) (BMNH) and is now known as the London specimen (Figure 1). The second skeleton, preserved in natural pose with extended wings, was acquired by the Humboldt Museum in 1881 and is designated as the Berlin specimen. Both skeletons demonstrate indisputable feather impressions of tail and wing plumage. Due to poor feather imprints, the other skeletons were initially unrecognized, and two were misidentified (see Table 1).

Because of the significance and transitional position of *Archaeopteryx*, the London specimen is probably the most valuable fossil (Charig 1979).

TABLE 1

Fossil Specimens of *Archaeopteryx*

Specimen	Date	Determined by	Feather Impressions	Notes
Single feather	1861	H. von Meyer	Good	
*Skeletons:				
London	1861	H. von Meyer	Good	Complete skeleton
Berlin	1877	H. von Meyer	Good	Complete skeleton
Maxburg	1956	K. Fesefeldt	Poor	Poorly articulated and badly decomposed; Currently in private collection
Teyler	1970	J. H. Ostrom	Poor	Found in 1855 and described as a pterosaur by H. von Meyer in 1857
Eichstatt	1973	F. X. Mayr	Poor	Misidentified in 1951 as *Compsognathus*

*The specimen is named after the museum or the location of the museum in which it is displayed.

Although the *Archaeopteryx* skeleton closely resembles that of a small coelurosaurian dinosaur, *Compsognathus* (Ostrom 1979, Padian 1985), its phylogeny and taxonomic status remain unclear. Padian (1985) argues that the only *new* avian characteristic of *Archaeopteryx* is its flight feathers, which are comparable to those of modern flying birds (Feduccia & Tordoff 1979), and that all the skeletal characteristics of *Archaeopteryx*, including the fused clavicles (furcula), were already present in coelurosaurian dinosaurs. At the 1984 International *Archaeopteryx* Conference held in Eichstatt, the consensus was that *Archaeopteryx* was a "bird," but not necessarily the ancestor of modern birds (Dodson 1985, Howgate 1985a). The discovery of *Archaeopteryx* coincided with a period of debate triggered by Darwin's recently published *The Origin of Species*. The appearance of *Archaeopteryx* rendered support for the arguments of the Darwinian evolutionary theory. Two prominent personalities involved in the controversy were Thomas H. Huxley, Darwin's champion defender, and Sir Richard Owen, an anti-evolutionist and advocate of the church. As superintendent of the British Museum, Owen was instrumental in obtaining the London *Archaeopteryx* (de Beer 1954, Feduccia 1980).

To test their hypothesis that *Archaeopteryx* had fraudulent feathers, Watkins et al. (1985a,b,c) and Hoyle et al. (1985), photographed the London specimen. Photographs of feather impressions of the fossil on both the

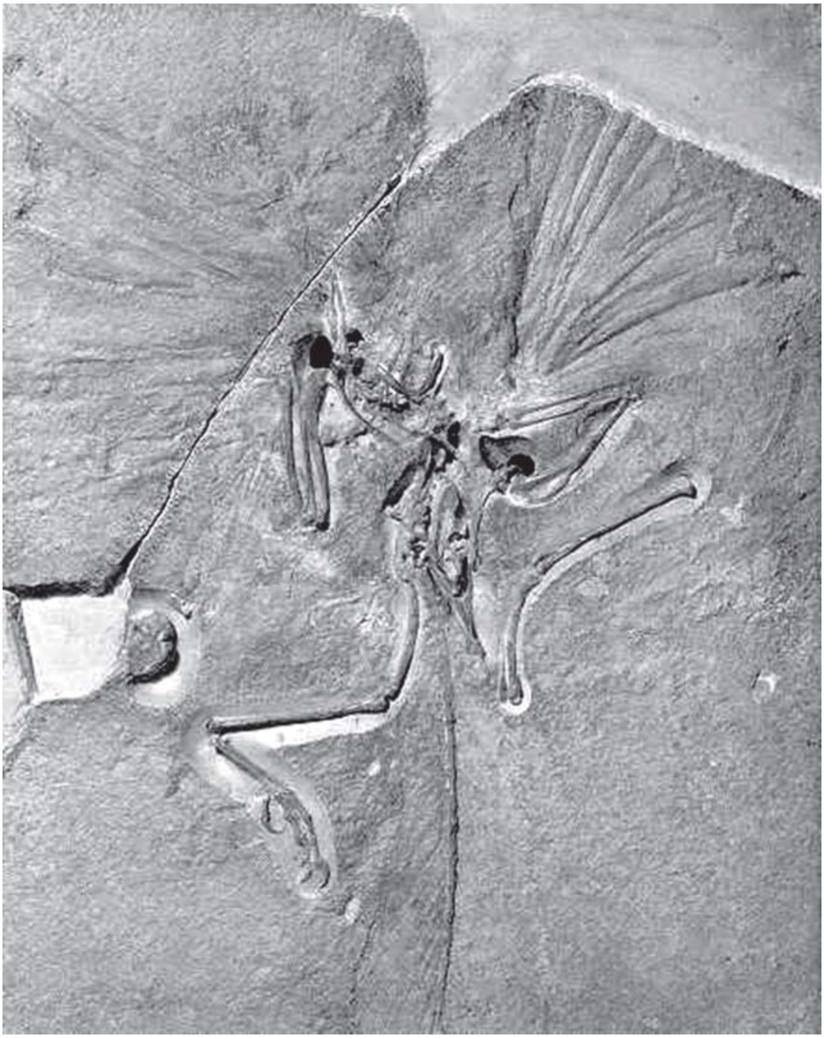

FIGURE 1. Holotype of *Archaeopteryx lithographica* (London specimen), preserved in dorsal position. Dendrites are the dark short branching fine lines seen near the top and along the main crack. Main slab (~~left~~ top).

Counterslab (~~right~~ bottom). Reproduced by permission of the British Museum (Natural History).

TABLE 2

Plumage of the London *Archaeopteryx*

Feather Impressions	Main Slab	Counterslab
Tail	Depressed by 2mm below surrounding rock	No corresponding elevation
Right wing	Many detailed vanes	Vanes without details
	Vanes demonstrating double-strike phenomenon	
	No corresponding depression	Small elevated region (“chewing gum” blob)
Left wing	Excavations at upper lef boundary since 1863	Elevated area of the wing now fits main slab depression

main slab and counterslab were compared. As summarized in Table 2 (tail and right wing) the two slabs do not appear to match (or be “mirror images”). Furthermore, a comparison of the present specimen with an 1863 drawing suggests an alteration has been made to the left wing of the specimen (Table 2). In 1863, the main slab and the counterslab could not have fitted together in this region.

Watkins, Hoyle and their collaborators concluded that the *skeletal* material of *Archaeopteryx* is authentic, probably from a flying reptile, but that the feathers were artificially imprinted on the fossil. They suggested the following procedure for creating the feather impressions: 1) the forgers removed rock from around the tail and “wing” (forelimb) regions, 2) they then applied a thin layer of cement, probably made from limestone of the Solnhofen quarries, to the excavated areas, and 3) they impressed feathers on the cement and held them in place by adhesive material (referred to as “chewing gum” blobs). Attempts to remove the blobs from the rock were obvious — the slabs were scraped, brushed and chipped. However, an oversight remained in the cleaning process: one “chewing gum” blob and fragments of others were left behind.

On March 31, Williams (1985) reported a proposal by the BMNH to investigate the possibility of a cement layer on the fossil. Their studies would involve: 1) removal of material from the edge of the fossil for microscopic sedimentation analysis to determine particle size differences between the surface and underlying areas, and 2) examination of the contact zone between surface and underlying material, utilizing electron microprobe analysis to compare the spectra emitted by the material. Further proposals to examine the authenticity of *Archaeopteryx* were submitted two weeks later by the editor of BJP (Vol. 132, p 375). These included: 1) direct physical testing of a small feathered region found on the counterslab, 2) carbon-14 dating of a sample of the "chewing gum" blob, and 3) spectrophotometry to analyze the blob for foreign elements at an unbiased laboratory. BJP offered to serve as a neutral observer.

In June, Hoyle et al. (1985) announced that BMNH experiments had been conducted, that the BMNH had determined the London *Archaeopteryx* to be authentic, and that the fossil was no longer accessible. Unable to test the authenticity of the plumage through direct physical examination of the fossil, Hoyle et al. (1985) explored various events induced by Darwin's introduction of the theory of evolution and the discovery of *Archaeopteryx* in the fossil record. They speculated that these incidents which hinted of conspiracy would appear inexplicable if the *Archaeopteryx* fossil were genuine, but logical if the fossil were fraudulent.

Without supporting references, Hoyle et al. (1985) asserted that from he early eighteenth century, the Solnhofen limestone area was notorious for its fossil forgeries and that genuine fossils, altered to form monsters, were sold to museums. After the publication of *The Origin of Species*, Huxley is said to have predicted the appearance of intermediate forms in the fossil record. Hoyle et al. suggested that this prediction initiated a search for such forms. It also prompted additional fossil forgeries.

Of the six *Archaeopteryx* fossils, only three specimens demonstrate undeniable feather impressions (see Table 1). Curiously, all three were linked with Hermann von Meyer, who described them within a period of less than two decades. His associates, the Haberlein family, acquired the two best skeletons (with good feather impressions) and sold them at exorbitant prices. Hoyle et al. postulated that Meyer and the Haberleins participated in forging the *Archaeopteryx* fossils and that Meyer was motivated by desire for distinction whereas the Haberleins were motivated by desire for wealth.

Although Richard Owen, the director of the British Museum, was an opponent of Darwin and Huxley, he expended almost two years of museum funds to acquire the controversial *Archaeopteryx*. Hoyle et al. proposed that Owen desired to set a trap for his antagonists with a fraudulent fossil.

On the other hand, if *Archaeopteryx* was a major cornerstone of Darwinian evolution, why was it mentioned only briefly in later editions of *The Origin of Species*? Hoyle et al. suggested that Darwin did not believe *Archaeopteryx* to be a true fossil.

In a presidential address to the Geological Society in 1870, Huxley spoke on "Paleontology and the Doctrine of Evolution" without mentioning

Archaeopteryx. Hoyle et al. again supposed that Huxley was silent because he knew about the *Archaeopteryx* fraud.

In the 1860 debate between the church and Huxley, Owen supported Bishop Samuel Wilberforce who lost the debate. The following conjectures from Hoyle et al. were: 1) Owen, filled with spite and paranoia, decided to snare both Darwin and Huxley by *Archaeopteryx*; 2) *Archaeopteryx* was a mockery representing an intermediate life form and was compatible to Darwin and Huxley's fancy and theory; 3) Huxley and Darwin, refusing to be trapped, remained silent to save their reputations; 4) Owen maintained his silence because he would have lost his respectability in exposing he fraud, especially since he had purchased the *Archaeopteryx* fossil.

The BJP papers evoked responses of outrage in defense of *Archaeopteryx* (Vines 1985, Howgate 1985b). The forgery charge, provoking a debate between physicists and paleontologists and perhaps an additional controversy between evolutionists and creationists, was emphatically denounced. Having suffered a loss of integrity from the Piltdown Man hoax, BMNH scientists could not ignore the charge (Broad 1985, Nield 1985). As a gesture of cooperation, it was suggested that museum paleontologists invite Hoyle and his colleagues to select the test sites (Williams 1985).

Siegfried Rietschel (1985), a taphonomist, also responded to the BJP forgery challenge. He stated that each of the known *Archaeopteryx* specimens demonstrates outlines of feathers, and that the Maxburg specimen has definite feather structures, complete with rachis and barbs. Rietschel indicated that the feather structures, regarded by BJP authors as feather impressions, are technically casts of feathers and are almost impossible to reproduce artificially.

Recently, Charig et al. (1986) reported BMNH findings on their study of the holotype of *Archaeopteryx*. A vertical section through the main slab of the fossils reveals no discontinuity between the true limestone and the "supposed layer of cement" which overlies it. In addition, there is no discontinuity around the perimeter of the "cement" (outer layer), and there is a complete absence of air bubbles between the outer layer and the limestone. "Chewing gum" blobs are considered to be natural irregularities of the surface of the limestone, because an organic adhesive substance (such as gum arabic, etc.) would have deteriorated with the passage of time. Ultimately, conclusive evidence of authenticity on the plumage of *Archaeopteryx* is manifested by matching hairline cracks and dendrites on the feathered regions on both slabs of the fossil (see Figure 1).

Scientific puzzles are not easily deciphered and the argument over *Archaeopteryx* is yet to be concluded. So the debate continues, and perhaps this intriguing case will never be resolved to everyone's satisfaction.

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E D I T O R I A L

DOUBLETHINK OF SCICOM

After reading George Orwell's book *1984* for the second time, I began to contemplate *doublethink* and the inroads it has made into our society and the scientific community (SCICOM). Orwell defined doublethink as follows:

> *Doublethink means the power of holding two contradictory beliefs in one's mind simultaneously, and accepting both of them.*

To me, one of the most interesting and alarming applications of doublethink in SCICOM is in the creation-evolution arena. In this area doublethink is interesting because of the many ways in which it is applied, and alarming because of the potential consequences arising from failure of the unsuspecting to understand that doublethink has been used. As the word implies, doublethink infers an alteration of truth of reality in order to accomplish a given purpose. The use of doublethink is not limited to either side of the creation-evolution conflict. As a matter of fact, at times it seems to be used freely by both sides!

A classic example of SCICOM's exercise of doublethink is the use of spontaneous generation as the beginning of all life, while at the same time presenting data which prove beyond a doubt that spontaneous generation is impossible.

Another example of the exercise of doublethink is the acceptance of a literal creation week while at the same time stating that the first few chapters of Genesis are allegorical.

Rather than dwell upon examples of doublethink, I would like to examine some of its consequences.

The continued use of doublethink raises the basic question, "Is there such a thing as truth or reality?" It tends to promote a philosophy of "mobile truth." Both of these results are apparent in our modern society.

The greatest use of "mobile truth" by SCICOM is in the interpretation of data. The same data set can be analyzed by individuals influenced by different paradigms, and different "truths" will emerge from the analyses. Which "truth" is correct? When paradigms are changed, the interpretation changes, while the original data set essentially remains intact! However, one must realize that the data set is, in part, dependent upon the paradigm of the original investigator.

If we scrutinize the differences in paradigms which give discordant interpretations of the same data set, we will find that the differences arise from the basic assumptions postulated in these paradigms. Intuitively, then, there must exist a set of inviolate assumptions which, when used, will yield concordant interpretations of data irrespective of paradigm or investigator. Such concordant interpretations could then be labeled TRUTH.

Doublethink cannot exist in the presence of TRUTH because of its incongruent nature. Therefore, if doublethink is used in or required by any paradigm, that paradigm *will* fail to yield TRUTH.

Consequently, the challenge to SCICOM, as well as other thought systems, is to avoid the use of doublethink and discover that set of inviolate assumptions which will lead to ultimate TRUTH. In so doing, no source should be arbitrarily set aside without careful investigation, because TRUTH has many vestiges, and its sources are many and varied.

Clyde L. Webster, Jr.

ARTICLES

SOME QUESTIONS ABOUT GEOCHRONOLOGY

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WHAT THIS ARTICLE IS ABOUT

The presently accepted geochronological time scale for the earth proposes an age of about 4600 Ma (4600 million years). Sedimentary layers found on the continents of the earth contain evidences of past life (fossils) dated from very recent to several thousand million years. Evolution of life is assumed to have taken place during that time. This scenario contrasts dramatically with the biblical creation account which proposes that life on earth has existed for only a few thousand years.

The geochronological time scale of thousands of millions of years is based mainly on radiometric dating — a dating system which has both strengths and weaknesses. On the other hand, some other time-dependent processes change at rates which challenge generally accepted geochronology. Examples include:

1. *The present rate of erosion of the land surface of the earth would level the continents several hundred times over in 4600 Ma.*
2. *Rivers carry sediment to the ocean at a rate that would fill the oceans at least 19× over in 3500 Ma, yet oceans are still very empty. Attempts to explain this by recycling sediments into the crust of the earth by various mechanisms are not very satisfactory.*
3. *Present rates of sediment formation indicate that there should be 14-23× as much as is found. Intermittent action is used as an explanation.*
4. *Mountains are rising at rates of 100 km in 100 Ma. Intermittent action is again used to explain the discrepancy.*
5. *In 3500 Ma, the present production rate of volcanic ejecta would produce 20-80× more than is now found.*
6. *The human population grows so rapidly that its present size could have been reached in less than 1% (3200 years) of the minimum time assumed (½ million years) for man on the basis of radiometric dating. Also supporting a recent existence for man are the historical and archaeological data which are abundant but very recent. It does not seem that man (Homo sapiens) has been on this planet for ½ million years.*
7. *On the other hand, the 4600 Ma assumed for the age of the earth is many orders of magnitude too short to account for the highly improbable events postulated for the evolutionary development of life.*

It appears that quite a number of independent factors disagree with the presently accepted view of 4600 Ma for the development of the present earth *system and the life contained therein. While the factors noted (except Factor 6) do not point to a few thousand years as indicated by the Bible, it is significant that the worldwide flood described in Genesis has the potential to cause Factors 1-5 to change more rapidly than at present and thus fit into the context of a few thousand years since creation. Creation itself has the potential to resolve any difficulty over the time required for evolutionary development (Factor 7).*

All extrapolations of present phenomena into the past must be approached with caution. A number of explanations have been proposed in the scientific literature for reconciliation of the discrepancies noted above with standard geochronology. These explanations propose that present geologic processes do not represent long-term averages. While this may be true in some instances, it is difficult to accept that all these various rates would be wrong. It appears that standard geochronological interpretations face some significant unresolved problems.

INTRODUCTION

One of the more significant differences between the concepts of creation and evolution is the amount of time required for the history of life on earth. Evolution proposes thousands of millions of years for the development of life to advanced forms. The biblical creation model proposes that life has existed for only a few thousand years.

Estimates of the age of the earth and the subsequent assumed time for the development of life have increased considerably during this century. Early concepts of ages of less than 100 Ma (100 million years) have gradually given way to figures more than 40× as long (Engel 1969). Recent views are based on radiometric dating which is presently the most accepted method of determining geologic ages. It is sometimes called “absolute dating” — a term that expresses the high regard given to this method. Based on the rate of disintegration of long-lived isotopes, estimates up to 6000 Ma (6,000,000,000 years) have been proposed for the age of the earth. Major agreement has been reached on an age of around 4600 Ma (Engel 1969). Within this time frame, there is general agreement that a major part of the continents (Kröner 1985) and oceans have existed for 3500 Ma. These latter long time concepts (4600 and 3500 Ma) will be designated in this essay as “standard geochronology.”

Radiometric age measurements sometimes disagree with one another and with other dating techniques. Damon & Kulp (l958), Brown (1983) and Taylor et al. (1985) refer to many examples. Disagreements are explained — sometimes with convincing argumentation — on the basis of inherited characteristics and/or subsequent geochemical disturbances in the rocks. However, the radiometric dates that provide the basis for the standard geologic time scale present a significant sequence. In addition to methods based upon radiometric dating, the slow rate of presently observed geologic changes also suggests that a great deal of time would be involved in the formation of some of the major features of Earth's crust, including the thick accumulations of fossil-bearing (evidence of past life) sedimentary layers found therein.

On the other hand, those who believe in creation as described in the Bible envision a short period of a few thousand years for the existence of life on our planet. This model includes a worldwide catastrophe — the Genesis flood — responsible for the rapid deposition of fossil-bearing sedimentary layers. This view is supported by the evidence of past catastrophic activity found in the sediments as well as the scarcity of evidence, especially in the main part of the geologic column, of the consequences that should have developed over long periods of time. Examples include the paucity of soils or preserved mature plant ecosystems. Deep erosional features such as buried canyons and cliffs should be much more abundant throughout the sedimentary layers, if these layers had been part of a sedimentary cycle existing over thousands of millions of years.

Each of the considerations listed above could be the subject of an extended discussion. This short survey will be limited to processes which, according to presently observed rates of change, appear to be in disagreement with the standard geochronological time scale of 4600 Ma.

Unfortunately, pertinent information dealing with this topic is not always firm. In many cases an undesirable, but unavoidable, degree of imprecision, conjecture and uncertainty is present. Nevertheless, the incongruities between some contemporary observations and standard geochronology are significant enough to suggest a reassessment of the currently accepted framework for geologic time.

1. RATE OF EROSION OF THE CONTINENTS

By noting the rates at which the surfaces of the continents are eroded and carried away by rivers to the oceans (see Section 2 for specific values), one can calculate the length of time required to remove a given thickness of the continents. Judson & Ritter (1964) have estimated that for the United States the rate of erosion averages 6.1 cm/1000 yr. At this rate of denudation the continents, which average 623 m above sea level, would be eroded to sea level in a mere 10.2 Ma. In other words, at this rate the present continents would be eroded over 340× in the 3500 Ma assumed for the age of the continents. The observation by the famous geologist Powell that "mountains cannot long remain mountains" certainly seems appropriate. The estimate of 10 Ma given above has been a well-accepted figure (Schumm 1963) and has subsequently been referred to in a number of publications including Dott & Batten (1971, p 136) and Garrels & Mackenzie (1971, p 114-115). Earlier, Dole & Stabler (1909) gave figures indicating that it would take about twice as long. Judson (1968), while correcting for human activity, suggests 34 Ma for complete erosion of the continents. None of these figures does much to alleviate the discrepancy which is especially significant when one considers mountain ranges such as the Caledonides of western Europe and the Appalachians of North America which are assumed to be several hundred Ma old. Why are these ranges here today if they are so old?

Rates of erosion are greater in high mountains and lower in regions of less relief (Ahnert 1970, Bloom 1971, Ruxton & McDougall 1967, Schumm 1963). Ruxton & McDougall (1967) report erosion rates of 8 cm/1000 yr near sea level and 52 cm/1000 yr at an altitude of 975 m in the Hydrographers Range in Papua. Rates of 92 cm/1000 yr are reported for the Guatemala-Mexico Border Mountains (Corbel 1959), 100 cm/1000 yr for the Himalayas (Menard 1961), and in the Mt. Rainier region of Washington Mills (1976) documents erosion rates of up to 800 cm/1000 yr. Probably the highest recorded regional rate is 1900 cm/1000 yr from a volcano in New Guinea (Ollier & Brown 1971).

It has been suggested that mountains still exist because they are constantly being renewed by uplift from below. However, this process of uplift could not go through even one complete cycle of erosion and uplift without eradicating the layers of the geologic column found in them. Present erosion rates would tend to rapidly eradicate evidence of older sediments; yet these sediments are still very well-represented, both in mountains and elsewhere.

Other attempts to reconcile average present erosion rates to geologic time include suggestions that man’s activities, especially agricultural practices, have increased the rate of erosion, making present rates uncharacteristically rapid. Such an explanation seems inadequate to account for a several hundred-fold discrepancy. Gilluly et al. (1968, p 79) propose that farming may have increased average erosion rates by a factor of less than 2, while Judson (1968) suggests about 2½×. Others have suggested that the climate of the past may have been more dry or the relief flatter, resulting in slower erosion rates. We now have some interior basins such as central Australia where there is no drainage and no removal of sediment, but these are exceptions. The lush vegetation evident in significant sections of the fossil record suggests at least some wetter conditions in the past. Characteristically, current erosion rates in hot, dry lowlands with gradients 0.001 or less, are not sufficiently slower. Corbel (1959) indicates rates of

1.2 cm/1000 yr for the hot dry plains of the Mediterranean region and New Mexico. The lowest rates found in a study of 20 river basins (Ahnert 1970) was 1.6 cm/1000 yr for basins in Texas and England. These slower rates do not solve a discrepancy of several hundred-fold, and one would have to postulate different past conditions for a major area of the earth during a significant proportion of earth history to provide a resolution to the problem.

A different context can serve to emphasize the question of rates of erosion. If it is assumed that 2.5 km of continents have been eroded in the past (our present continents average about one fourth that thickness above sea level) and if it is assumed that erosion proceeds at the rate of 3 cm/1000 yr (half of the presently observed rate to correct for the effects of modern agricultural pursuits), then it would take about 83 Ma to erode a 2.5 km thickness of continental crust. In other words, at present rates of erosion, continents 2.5 km thick could have been eroded 42× during the assumed 3500 Ma age for the continents, or continents 106 km thick would have been eroded once. There is little question that there is some difficulty in reconciling present erosion rates with standard geochronology.

2. SEDIMENTS CARRIED TO THE OCEAN

Rivers and glaciers carry sediments and dissolved chemicals to the ocean, ocean waves erode the continental coastlines, and wind carries some fine sediment to the ocean. All these factors, along with submarine volcanism, contribute to the sediments that accumulate in the ocean. The observed rate of transfer of sediments from the continents to the ocean seems too rapid to be readily reconciled with standard geochronology. Most of the sediment going into the ocean is transported by rivers. Estimates of sediment transport to the ocean for the world (Table 1) vary from 8000-58,000 million metric tons/yr (Holmes 1965, p 511; Holeman 1968; Jansen & Painter 1974; Milliman & Meade 1983). Many of the estimates do not take into account the bedload which represents the sediments that are rolled or pushed along the bed of a river and which is not readily observed at river gauging stations. Sometimes the bedload is arbitrarily estimated at 10%, because it is so difficult to measure (Blatt et al. 1980, p 23; Schumm 1963). Jansen & Painter (1974) suggest that 26,700 million tons/yr for global denudation "is likely to be an underestimate." Gilluly (1955) estimates that 13.6 km^3 of solid material are carried to the world oceans every year. This corresponds to about 31,000 million tons/yr. At this rate the ocean basins (including their present sediments), which have a total volume of 1550 million km^3, should be filled in just 114 Ma. Using a more conservative estimate of river transport

TABLE 1
Some Estimates of the Rate at which Sediments Reach the Ocean*

Author (Date)	Thousand Million Metric Tons/Year
Fournier (1960)	58,100
Gilluly (1955)	31,800
Holeman (1968)	18,300
Holmes (1965)	8,000
Jansen & Painter (1974)	26,700
Kuenen (1950)	32,500
Lopatin (1952)	12,700
Milliman & Meade (1983)	15,500
Pechinov (1959)	24,200
Schumm (1963)	20,500

*Based on publications of Holmes 1965, p 511; Holeman 1968; Jansen & Painter 1974; and Milliman & Meade 1983.

of sediment to the ocean of 20,000 million tons/yr, it would still take only 178 Ma to fill these ocean basins with sediment. In other words, the present rate of transport of sediment by rivers could fill the oceans 19× in 3500 Ma. Of course, the oceans, which average 3.8 km in depth of water, are not at all full of sediment; and in much of the deep oceanic abyssal plains, sediment thickness averages only a few hundred meters. It would take about 50 Ma to produce the generous estimate of 435 million km^3 (Ronov & Yaroshevsky 1969) of sediment now found on the ocean and continental margins. One could argue that the continents were smaller in the past and produced less sediment. Such an argument would not resolve this discrepancy unless the continents were extremely small, and there is broad, but not unanimous, agreement that they have been near present size for the past 2500 Ma (Kröner 1985; Taylor & McLennan 1985, p 234).

On the other hand, three scenarios suggested within the standard geochronological paradigm may help alleviate some of the time discrepancy: a) the sediments are subducted into the earth at the deep trenches along the plate margins, as proposed by the plate-tectonics model, b) the sediments which originally came from the granitic continental crust are recycled again to form new continental crust by accretion or rifting processes, c) the river sediment which accumulates at the margins of the continents is recycled into other sediments again to be eroded. None of these scenarios provides a satisfactory explanation. They will be discussed in the order listed.

a) It is sometimes proposed that the reason there is so little sediment in the oceans is that the oceanic crust is too young, the older ocean floor and sediment having been subducted into the mantle of the earth. However, subduction of sediments is not going on at a rate that would keep up with the supply given by rivers (Karig & Kay 1981, Kay 1980, Veizer & Jansen 1979). Li (1972) has estimated the subduction rate to be at 2500 million tons/yr, in contrast to present river delivery of 20,000-30,000 million tons/yr. Lisitsyn et al. (1982) estimate subduction at about 3000 million tons/yr, while Howell & Murray (1986) propose that only 21% of the sediment load of rivers ends in the oceanic trenches where subduction occurs. Furthermore, one must take into account that the major repositories of sediments from big rivers on the floor of the ocean are geographically unrelated to subduction zones (Potter 1978; Taylor & McLennan 1985, p 240-241).

b) Probably the most serious problem faced by those who propose a recycling of sediments into the thick "granitic" crust forming the continents is the mismatch between the chemical composition of sedimentary and of igneous-metamorphic (granitic) rocks. The original granitic rocks are assumed to have been the parent source of the sediments which in turn are changed from sediment back to the igneous-metamorphic rocks forming new continental crust. The main mismatch is with sedimentary limestones which have a proportion of elements that is different from the proportion in the supposed parent-daughter igneous-metamorphic rocks (Garrels & Mackenzie 1971, p 237). The difference is emphasized by the fact that one finds more than twice as much limestone in the sedimentary rocks as would be expected if they were derived from igneous rocks. The average of 5 studies (Pettijohn 1975, p 21-22) involving direct measurement indicates 20% limestone, while the average of 4 studies utilizing calculations from the composition of igneous rocks indicates only 8% limestone. Also, the average igneous rock has more than 3× as much sodium as the average sedimentary rock (Garrels & Mackenzie 1971, p 237). The latter authors also indicate that carbon, which forms several percent (4.7% — compared as oxide) of sedimentary rocks, is present only as a trace in igneous rocks. It is sometimes assumed that carbon had to come originally from a degassing process from the planet's mantle. The general picture is that there are some significant differences in the elemental composition of sedimentary and igneous rocks. The kinds of minerals found in the two are very different. Mention should be made of Garrels & Mackenzie's (1971, p 248) effort to resolve the question of the origin of limestone from igneous rocks by proposing that limestone could be derived in part from very large quantities of Precambrian volcanic sediments.

c) If only sediments at the continental margins are involved in the recycling process, the rate of discharge of sediments from rivers is so great that very rapid recycling would be required. These rates seem too high to have preserved the older sediments that still exist. Ronov & Yaroshevsky (1969) estimate the volume of sediments on the continental margins to be 190 million km^3, equivalent to 8×10^{17} tons. One can conservatively assume that before the development of agriculture the rivers carried an estimated 10,000 million tons annually to the ocean, and 20% of this went to the deep trenches. According to the recycling of sediments model, the remaining 8,000 million tons/year must be recycled into other sediments near the continental margins. At this rate the 8×10^{17} tons would be recycled on an average once every 100 Ma (8×10^{17} divided by 8×10^9). Yet major parts of the geologic column considered much older than this are found on the continental margins and on areas considered to have been continental margins, including unique abundant Paleozoic and significant Precambrian limestone deposits. There are major deposits of Precambrian sediment older than their putative 600 Ma age in many regions of the world. Estimates of the proportion of sediments that are Precambrian vary from $^1/_5$ to $^1/_2$ (Garrels & Mackenzie 1971, p 249). It does not seem that if there was general recycling at the rate of once every 100 Ma, there would be very much of these ancient sedimentary deposits still preserved. One would also expect considerable recycling of fossils which usually appear in their primary unique position of burial in the geologic column. Furthermore, it does not seem satisfactory to suggest that rapid recycling has taken place only within very limited parts of the geologic column. That does not appear to be occurring now. Usually major sections of the geologic column are exposed and eroded in our river basins. Both young and old sediments are involved in much of the erosion now observed. Restricted recycling is not normative to our present earth.

It appears that the rivers carry sediments to the ocean at a rate that is too rapid to easily accommodate the long periods of time proposed by standard geochronology.

3. RATE OF SEDIMENT ACCUMULATION

{6 Jan 2000 note by author: this section may need updating}

Around the turn of the century a number of studies compared observed rates of accumulation of sediments with the maximum thickness obtainable from the various individual parts of the geologic column (e.g., Figure 1) over the world. These maxima sometimes totaled more than 100,000 m in thickness. While the results obtained are highly variable, present rates of deposition of sediments are so rapid that they all point to a younger age than that of standard geochronology. Eicher (1976, p 14) gives a summary of 19 such studies which average 246 Ma, or $^1/_{14}$ of the 3500 Ma of standard geochronology.

FIGURE 1. Deep sedimentary layers found on the east end of the Grand Canyon of the Colorado River in Arizona. Sediments are quite abundant in many localities, but much less is present than would be expected over thousands of millions of years.

Other more recent studies also support a paucity of sediments when compared to long geologic time. Gregor (1968) attributes to episodism (i.e., various episodes with differing rates of activity) the discrepancy between the relatively small amount of sediment present and the thousands of millions of years for sediment production. Assuming a rate of denudation to produce sediments at the rate of 3 cm/1000 yr, he suggests that in 3500 Ma, 23× as much sediment as now exists should be present. At this assumed rate the present sediments would have been produced in about 152 Ma.

A number of studies (see Gilluly 1949 for listing) have shown the intriguing relationship that younger sediments show greater thickness per equivalent unit of time than older ones. In other words, the rates of deposition appear more rapid for more recent deposits. Conversely, one could also interpret this as meaning that the time assumed for the deposition of older sediments is inordinately long. Newell (1972) gives a set of examples starting with slow rates of 0.6 to 6 cm/1000 yr (Kay 1955) for average deposition since the Precambrian and ending with Rusnak's (1967) estimate of a current rate of 100 to 200 cm/1000 yr for bays, estuaries, and lagoons. Much more rapid rates are observed in exceptional cases such as the Mississippi delta (30,000 cm/1000 yr), but these exceptions have limited significance for the general picture. The comprehensive data of Sadler (1981) based on 25,000 samples emphasizes the reality of the general picture presented above, and there is general agreement that present rates of sediment accumulation appear faster than can be easily extrapolated to the past.

Several explanations have been proposed. It is commonly suggested that we are in a period of rapid sedimentation. In the past the mountains were lower, hence erosion and deposition was slower (see Gilluly 1949 for review). Incidentally, a low topography for the past fits well with several models of the Genesis flood presently under study. Another explanation is that the farther back one goes in time, the more incomplete the record is (Gilluly 1949, Sadler 1981). The argument is that the more time there is, the greater the opportunity for periods of non-deposition to occur. If episodism is a highly random factor, such an explanation seems plausible. Still others propose that recycling of sediments has transferred older sediments into younger ones (Garrels & Mackenzie 1971, Veizer & Jansen 1979), hence the scarcity of the older sediments. In Section 2 we discussed some of the problems with recycling. On the other hand, the observed general decrease in the volume of sediments through time (as one goes down the geologic column) agrees with recycling. This observation might also be interpreted as a phenomena of basin infilling where the older (lower) sediment would have smaller volumes due to greater restriction in the lower regions of depositional basins. Regardless, the general decrease in sediment volume as one goes back in geochronological time is quite erratic (see figs. 10.1 and 10.9 in Garrels & Mackenzie 1971). It is irregular enough that Gregor (1968, 1970) proposes two cycles of sediment building instead of the usual one within the Phanerozoic. One can also consider the possibility that the reason for the scarcity of sediments in the past is not slower rates of accumulation but a shorter time for accumulation. Regardless of interpretation, there is an incongruity between present sediment rate production and the amount expected over the time proposed by standard geochronology.

One might wonder whether erosion of the continents is so rapid (Section 1) that we would not expect to see much sediment anyway. Erosion both produces and transports sediment, but the sediment must be deposited somewhere, and we should find it, unless it has been recycled. However, as shown in Section 2, recycling is not an easy answer.

4. RATES OF UPLIFT OF MOUNTAINS

Our “solid earth” is not as firm as we usually surmise. When careful measurements are made, we find that some areas of the continents are slowly rising, while others are subsiding. Current rates at which these changes are occurring are too rapid to represent long geologic processes over many millions of years.

There are two main methods of establishing the rate of orogeny (uplift) of mountains. One is by direct precise measurements noting accurately the altitude of a mountain at a given time and remeasuring its height a few years later. This gives the observed rate of uplift. The other is by indirect "geologic studies" comparing the height of a mountain with the time assumed for uplift based on standard geological and geochronological interpretations. This latter method gives average assumed rates. Measured rates of uplift are more rapid than those based on indirect geochronology. For instance, current uplift of the eastern and central part of the Alps of Switzerland (Figure 2) is about 100-150 cm/1000 yr (Mueller 1983) when measured directly. Using indirect geological studies gives a rate of only 3 cm/1000 yr (Zeuner 1958, p 360), or 3% of the present measured rate.

Schumm (1963) states that "Rates of orogeny being measured at the present instant of geologic time [direct precise measurement] are far in excess of the minimum values obtained by geologic studies." Schumm reviews some of the literature dealing with present rates of orogeny and

FIGURE 2. View looking southwest into the central Alps as seen from Gornergrat, Switzerland. Precise measurements show that this region is rising at the rate of about 1 mm/yr. This rate, if extended over 100 Ma, would raise the region by 100 km. Three glaciers are evident across the valley.

concludes that mountains form at a rate approaching 760 cm/1000 yr. The same rates are found in southern California hills (Schumm 1963) and the southern Appalachians (Hand, quoted in Press & Siever 1982, p 484) where there has been no glaciation that might induce some orogeny due to ice removal. In Japan Tsuboi (1933) measured rates as high as 7200 cm/1000 yr. Blatt et al. (1980, p 30) state that “rates of uplift of mountains are fast,” ranging from 300-1000 cm/1000 yr. Hand (quoted in Press & Siever 1982, p 484) reports present-day regional uplift in the Rocky Mountain region of 100-1000 cm/1000 yr, and 0-1000 cm/1000 yr are indicated for the Appalachian region. On the other hand, areas such as parts of the east and southern coast of the United States are subsiding at comparable rates. Senftl & Exner (l973) report orogeny of 100 cm/1000 yr for the Hohen Tauern of the Austrian Alps. Precise direct measurements are not available for the Himalayas; however, on the basis of geomorphic evidence, also the finding of recent tropical plant and rhinoceros fossils which appear uplifted 5000 m, and on the basis of tilted beds, an estimate of a present uplift rate of 500 cm/1000 yr is proposed (Gansser 1983). It also appears that Tibet has been uplifted at a similar rate. On the basis of geomorphic and erosion data, the same author estimates an uplift rate of about 300 cm/1000 yr for the central Andes.

The rate of 760 cm/1000 yr proposed by Schumm (1963) would yield an uplift of 7.6 km in 1 Ma. Using a more conservative rate of 100 cm/1000 yr still suggests that the process could not continue over very long periods of time at the present measured rates, for at this rate the height of mountains could theoretically reach 100 km in 100 Ma. To explain the discrepancy a special case is proposed where mountains rise with “‘pulses’ of rapid uplift” (Blatt et al. 1980, p 30). Schumm (1963) also suggests that these data support rapid uplift with little time for erosion before uplift is completed. Recognizing that the present rate of uplift cannot be extended throughout standard geochronology, these authors explain the difference by episodism. The present is assumed to be in a period of rapid orogeny.

It should be noted that the rapid rates of erosion presently occurring are too slow to keep up with the rates of uplift noted in mountain formation. Schumm (1963) points out that modern rates of orogeny of 760 cm/1000 yr are about “8 times greater than the average maximum rate of denudation.” Blatt et al. (1980, p 30) illustrate the same point by referring to the fact noted above that erosion is more rapid in high mountains and gradually decreases toward lower elevations. Using the data of Ahnert (1970), they estimate that for erosion to keep up with a “‘typical’ rate of mountain uplift” of 1000 cm/1000 yr, a mountain would have to be in the order of 45 km high. The present rate of uplift of mountains is too rapid to fit directly into standard geochronology.

One might ask if the rapid rate of uplift of mountains now observed does not negate the first point presented earlier that the continents including their mountains should have been eroded several hundred times over in the thousands of millions of years of their proposed existence. The challenge to standard geochronology is that if mountains have been uplifting at current rates or even much slower, the lower parts of the geologic column which are many hundreds to thousands of millions of years old should have been uplifted and eroded away long ago. Yet these older sections are very well-represented in our mountain ranges, as cursory field study or examination of geologic maps will reveal.

5. EMISSION OF VOLCANIC EJECTA

Gregor (1968), while proposing episodism, has indicated that on the basis of an estimated 1 km^3 of volcanic ejecta/yr on the earth, there should be an average layer of volcanic deposits 7 km deep in 3500 Ma. Gregor's figure of 1 km^3/yr seems supported by recent volcanic activity. Izett (1981) lists the volume of some of the more notable ash beds formed from volcanic activity: Tambora (Indonesia, 1815) — 100-300 km^3, Krakatoa (Indonesia, 1883) — 6-18 km^3, Katmai (Alaska, 1912) — 20 km^3, Mt. St. Helens (Washington, 1980) — 1 km^3. Mt. St. Helens ejected a significant volume of other volcanic products in addition to the ash considered above. To be added to this list are the numerous smaller volcanic events over the surface of the earth, such as occur periodically in Hawaii, Indonesia, Central and South America, Iceland, Italy, etc. All of this should average quite a bit more than 1 km^3/yr. Decker & Decker (1982, p 47) suggest an average volcanic output of about 4 km^3/yr. Estimates of the quantity of volcanic products now found on the earth are difficult to determine because of the problem of identification and because of mixing with other sediments. Garrels & Mackenzie (1971, p 249) suggest that 25% of the volume of sediments are volcanic in origin. One can obtain an estimate of the volume of volcanic products by applying this proportion to the total sediment volume of the earth. Pettijohn (1975, p 20) lists 8 estimates of the total volume of sediment. They average 683 million km^3. If 25% of this is volcanic, we get a figure of 170 million km^3 of volcanic ejecta on the earth. If we use the estimate of Gregor (1968) of volcanic production of 1 km^3/yr, we would get 3500 million km^3 in 3500 Ma, which is 20× as much as appears to be present. If we use the estimate of Decker & Decker (1982, p 47) of production rate of 4 km^3/yr, we would expect 80× as much as now appears present.

The simplest way to solve the discrepancy within a standard geochronological paradigm is to suggest episodism (Gregor 1968) and assume that we are in a much more active period of volcanic production. Another way is to recycle past production into the earth. Some of the problems of recycling were considered in Section 2. If one excludes these alternatives, a present rate of production by volcanoes of 4 km^3/yr when extended over 3500 Ma would exceed the total volume of the crust of the earth.

6. HUMAN POPULATION GROWTH RATES

It does not take much reflection for us to realize that mankind is a growing and ubiquitous entity on the face of the earth. Overcrowding is a serious and all-too-common problem. World population is growing exponentially, doubling every 35-40 years (Information Please Almanac 1986, p 132). Calculating backwards from the present (in reverse) at this rate, one would come to two individuals (necessary to start a population) in a mere 1100 or 1200 years. Data based on growth from the middle of the 17th century to the present suggest a slower rate of growth according to which the present world population would have been produced in about 3200 years. To account for the ½ Ma assumed for the existence of man according to radiometric inference, it is suggested that man (here limited to *Homo sapiens*) did not reproduce as rapidly in the past. However, the discrepancy is so great that it seems proper to ask if man has been here for ½ Ma or more. Why has the earth become heavily populated only very recently? Figure 3, based on Coale (1974), illustrates the contrast between present growth rates and proposed earlier rates based on assumed long ages for man. (Coale uses a broader definition for man; hence his time span is greater than ½ Ma.) Coupled with the population growth considerations is the brief period of a few thousand years for the archaeological and historical data left by man. If man has been on earth for ½ Ma, should not archaeological and historical records extend further back in time? Should we not find firm evidence of human activity such as cities and roads hundreds of thousands of years old? Good evidence of past human activity is abundant and very recent. All three of these factors, the historical, the archaeological, and the biological rate of reproduction — suggest that man has been here for only a small fraction of the time proposed by standard geochronology.

The usual explanations given for the sudden change in rate of growth are that the development of agriculture a few thousand years ago permitted man to reproduce faster (Coale 1974), or that man may be more healthy now. Before this, man is assumed to have been a hunter and gatherer and/or more critically affected by disease. However, one can ask why man

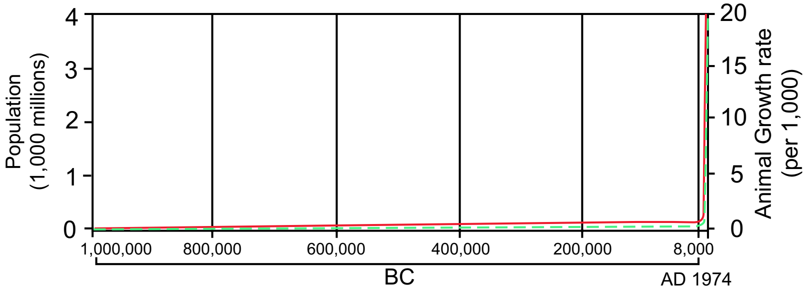

FIGURE 3. Overview of the size of the human population and its rate of growth based on assumptions that man has been on this planet for a million years. The solid line represents population; the dashed line represents rate of growth. The curves show a distinct change during the last few thousand years. Curves based on Coale 1974.

with all his inventive faculties as seen in the myriads of inventions about us should wait about ½ Ma to develop agriculture or health principles. The data seem to suggest that man has not been here for the time proposed by standard geochronology.

It can also be argued within an evolutionary paradigm that man could have become more advanced by some rapid evolutionary changes. However, the very recent appearance of major advances in man in contrast to the earlier slow evolutionary developments demands explanation.

While the question of man's past is a complex one, and significant caution seems warranted, his rather sudden authentication seems to provide some basis for questioning the putative antiquity which geochronology implies for him.

7. TIME REQUIRED FOR BIOLOGICAL EVOLUTION

Charles Darwin (1809-1882) refined and popularized the concept of organic evolution in his work *The Origin of Species* (1859). He knew that his proposal of small random changes guided by natural selection would require enormous amounts of time for the production of successful complex organisms. He suggested that 300 Ma had elapsed since the last part of the Mesozoic Era (Eicher 1976, p 10). Interestingly this is more than 4× longer than the 65-70 Ma proposed for this period by standard geochronology. While Darwin's view can now be considered only of historical interest, it is noteworthy that even then he was keenly aware of the tremendous amount of time necessary for the improbable events postulated by his theory.

This problem has taken on more significance in the context of modern molecular biology. For instance Eden (1967) in *Mathematical Challenges* *to the Neo-Darwinian Interpretation of Evolution* infers that an assumed age of 5000 Ma for the earth is far too short for the improbable events proposed by current evolutionary concepts. Eden uses the well-studied bacterium *Escherichia coli* as an example. In the genetic information found on the chromosomes of this and other organisms, a double order is found.

The chemical pattern for the composition of the genes themselves is one order of information, but in addition the genes are found on the chromosomes at specific localities which are related to the order of use by the organism for sequential biochemical changes. Aside from the problem of evolving the genes, one wonders how the genes became located in their proper order. Eden addresses the simple question of getting only 2 genes in order. It is postulated that these genes evolved earlier at random localities on the chromosomes. Eden estimates that it would take 5000 Ma for the changes necessary to bring 2 genes in their proper order of use. This calculation is based on observed rates of reproduction and the generous assumption that this bacterium would have been spread over the earth in a layer 2 cm thick for that extended period of time. The 5000 Ma give no time for the genes to evolve — a much more complex process —, nor does it give time for the evolution of other organisms, some of which are several hundred times more complex. Suffice it to say that many orders of magnitude of time more than the 4600 Ma postulated for the earth are required for the improbable events of the scenario of organic evolution.

Evolutionary biologists have studied a number of factors that might increase the rate of evolutionary change. Considered especially significant are changes in regulatory or control genes (Hedrick & McDonald 1980, MacIntyre 1982) which may be more influential than ordinary genes. However, the evolutionary significance of regulatory genes would have little to do with the time problem posed above about the order in gene location.

In the case of the evolutionary development of complex biological systems by naturalistic means, we find a factor that requires much more time than that provided by the standard geochronological time scale. The significance of this is complex. In a purely naturalistic context it raises questions about the validity of geochronology which thus appears too short. In a broader context that includes the possibility of creation, the time incongruity would be resolved.

SOME INFERENCES FROM THE DATA

The time conflict between some observed phenomena and standard geochronology are summarized in Table 2. While some of these factors are subject to further adjustments, one gets the impression that within the

TABLE 2

Factors in Conflict with Standard Geochronology

Factor	Suggested Degree of Conflict
1. Present rate of erosion of continents	Continents would be eroded 170-340× over in 3500 Ma.
2. Sediments carried into the ocean	Present rate would produce sediments now found in oceans in 50 Ma and would fill the oceans 19× over in 3500 Ma
3. Rate of sediment accumulation on continents	In 3500 Ma, there should be 14-23× as much sediment as found, excluding some limited recycling.
4. Rates of uplift of mountains	Mountains are rising at a rate of 100 cm/1000 yrs, which would result in mountains 100 km high in 100 Ma.
5. Rate of production of volcanic ejecta	In 3500 Ma 20-80× as much volcanic ejecta as we now find would have been produced.
6. Growth of human population	Present population size could be reached in 3200 years, while man is assumed to have been here for over 100 times longer.
7. Time for evolutionary development	Many orders of magnitude more than 5000 Ma are needed for the improbable events postulated.

context of standard geochronology a number of factors are currently changing at inordinately rapid rates.

The scientific literature suggests some explanations as given above for each case. However, how can one plead a variety of special cases for time-dependent factors and still maintain confidence in current geochronological interpretation? It is logically unsettling to sometimes claim consistency between the present and the past, and then plead for special cases when the data do not fit accepted views. There seems to be some basis for wondering if the paradigm of standard geochronology has been given unwarranted acceptance. While man's meager knowledge makes inconsistencies unavoidable, when we face a number of them, it may be time for some reevaluation.

Simple reflection on the time factors described above would likewise raise questions about inconsistencies between the data presented and the short time period for life on earth as proposed by the biblical model of creation. Most of the data presented above, except Factor 6, do not point to a few thousand years. For instance, if mountains are rising at the rate of 1 km/Ma, why are some mountains so high if they are so young? However, the biblical creation model (Neufeld 1974) includes both a creation by God and a worldwide flood that was a major catastrophe which dramatically changed the surface of the earth. Such unique events are difficult or impossible to analyze quantitatively, but they carry the potential to solve the discrepancies between the 7 factors listed in Table 1 and a short period of a few thousand years proposed by creation. The inordinately rapid rates in Factors 1-5 may reflect the effects of a single recent catastrophe such as the flood described in Genesis. Such a worldwide catastrophe would dramatically increase rates of erosion and sediment deposition, and such changes could be associated with mountain formation and even volcanism. Our present rates of change may reflect uncompleted adjustments to such an event. Supporting the plausibility of such an event is the fact that rapidly moving water increases its sediment transporting capacity (Figure 4) as the 3rd or 4th power of its velocity (Holmes 1965, p 512). In other words, if one increases the speed of flow 10×, moving water can carry 1000-10,000× as much sediment. Such figures make the laying down of large sedimentary deposits, during a single worldwide flood event, appear highly feasible. A recent creation would also solve the

FIGURE 4. Kanab Creek in southern Utah. A flash flood in 1886 cut a channel 15 m deep and 80 m wide in less than 8 hours (Gilluly 1968, p 218).

problems of both the rapid human population growth rate and the lack of time for evolution of major life forms (Factors 6 and 7). One might argue that by invoking creation and a flood, one is likewise pleading a special case. However, creation and the flood are not such special cases for the biblical creation model; they are implicit to the model.

Even though the supernatural involvements which are implied in the postulated unique events of creation and the flood cannot be scientifically tested, we can evaluate evidence related to these such as a long or short time span for earth history, evidence of catastrophism, and plausibility of evolutionary changes. In our search for truth, it is better to acknowledge the possibility of unique events such as creation and the flood rather than to assume they did not occur.

CONCLUSION

There are geological and biological factors which are currently observed to change at rates that are in disagreement with the standard geochronological interpretation of thousands of millions of years for the development of the crust and of life on earth. A number of alternative explanations have been proposed to bring about reconciliation, but these involve postulating an unsatisfying variety of special cases.

Evaluating factors dealing with the past warrants a great deal of caution. Extrapolation from the present involves some risk, and new observations and interpretations can readily alter conclusions for a past that is difficult to analyze. These problems apply to all dating scenarios. On the other hand, the recognized discrepancies with standard geochronology described herein appear significant and are based on several different tests. Because of this, some alternative views to standard geochronology appear credible.

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NEWS AND COMMENTS

CREATION-SCIENCE AND THE LOUISIANA BALANCED-TREATMENT ACT

On Wednesday, December 10, 1986, the merits of the Louisiana Balanced Treatment of Creation-Science and Evolution-Science Act (see *Origins* 12:38-40; 13:36-37) were heard by the nine justices of the U.S. Supreme Court. Representing the State of Louisiana, attorney Wendell R. Bird argued that the statute intended to ensure that *all* the scientific evidence for origins — including evidence supporting creation-science — would be taught in public-school science classes. Jay Topkis, a New York City lawyer representing the American Civil Liberties Union (ACLU), contended that creation-science was merely pseudoscience and that legal attempts to enforce its teaching were promoted by Christian fundamentalists who wanted to "give God equal time" with "godless evolution."

The court is expected to rule on the case by July. The final decision will depend upon the justices' perception of the statute's intent. If its primary purpose is perceived as promoting religion, it will be considered a violation of the U.S. Constitution's prohibition against the establishment of religion.

Previous decisions by lower courts reveal a tendency for judges to equate presenting scientific evidence for creation-science with indoctrination in religion. They have consistently overruled the creationists' appeals for "academic freedom," "equal time," "alternative views," and "fairness" by agreeing with the evolutionists' charges that creation-science is a religious belief and that laws to enforce its teaching are unconstitutional.

Opponents of "Scopes Trial II" lawsuits are alarmed by the support given to legal measures to enforce the teaching of creation-science in science classes. They fear that "balanced treatment" is only the first step in the process whereby evolution will be limited in presentation and eventually banished from the science classes not only in Louisiana, but throughout the United States. Martha Kegal, president of the Louisiana ACLU, describes the Balanced-Treatment Act as "the latest wrinkle in a century-old attempt to ban the teaching of evolution."

If the Louisiana Balanced-Treatment Act is struck down because creation-science is not perceived as having a secular intent, evolutionists will consider it a major victory. Perhaps in future lawsuits, creationists can then return to emphasizing the "free exercise of religion" clause of the

First Amendment to the U.S. Constitution by arguing that even though creation theory has a religious basis, the scientific evidence which supports it should be presented in public-school science classes.

Katherine Ching

ANNOTATIONS FROM THE LITERATURE

ANTHROPOLOGY

Walker A, Leakey RE, Harris JM, Brown FH. 1986. 2.5-Myr *Australopithecus boisei* from west of Lake Turkana, Kenya. Nature 322:517-522.

> ***Summary.*** This new find of two partial craniums of the homonid *Australopithecus* has been hailed as the most significant find in paleoanthropology since "Lucy" was discovered in 1974. The authors indicate that the features suggest a need for revision of traditional evolutionary patterns in the australopithecines — the assumed distant ancestors of modern man. The new find, which is not going unchallenged, promises to complicate an already confusing pattern for the assumed evolution of man.

CRETACEOUS EXTINCTION EVENT

Hutchison JH, Archibald JD. 1986. Diversity of turtles across the Cretaceous/Tertiary boundary in northeastern Montana. Palaeogeography, Palaeoclimatology, Palaeoecology 55:1-22.

> ***Summary.*** The Hell Creek and Tullock formations contain many turtles, and span the Cretaceous-Tertiary boundary. Over 3000 specimens were counted on a modified minimum number basis from 510 localities. At least 15 of about 19 Cretaceous genera and subgenera survive into the Paleocene. The magnitude of the change in diversity is less than or comparable to examples within the Tertiary. These data do not support a unique comprehensive extinction at the end of the Cretaceous as postulated on the basis of Iridiurn concentrations.

Sloan RE, et al. 1986. Gradual dinosaur extinction and simultaneous ungulate radiation in the Hell Creek Formation. Science 232:629-633.

> ***Summary.*** The number of genera of dinosaurs shows a progressive decrease, beginning below the Cretaceous-Tertiary boundary. Seven genera of dinosaurs are found in a channel fill with Paleocene (Tertiary) pollen and mammal fossils. This evidence is interpreted to show that dinosaurs did not suddenly disappear, but that they were declining before the end of the Cretaceous. This conclusion casts doubt on the end-Cretaceous asteroid impact hypothesis. The decline in dinosaur diversity is instead attributed, at least in part, to the rise of ungulate mammals, whose remains increase in diversity as dinosaur diversity

decreases. For reactions to this article and further discussion, see Letters, Science 234:1170-1175.

DATING METHODS

Taylor RE, Payen LA, Prior CA, Slota PJ (Jr), Gillespie R, Gowlett JAJ, Hedges REM, Jull AJT, Zabel TH, Donahue DJ, Berger R. 1985. Major revisions in the Pleistocene Age assignments for North American human skeletons by C-14 accelerator mass spectrometry: none older than 11,000 C-14 years B.P. American Antiquity 50:136-140.

Summary. This paper reports on significant revisions in dating the early human population in North America. Eleven skeletons, previously dated mainly by amino-acid dating to about 70,000(?) years, are redated by accelerator mass spectrometric analysis of radiocarbon to a maximum of 7900 years. Some examples include:

Original Dating (amino-acid and other techniques)		**Now Dating** (radiocarbon years)
70,000(?)-8300	revised to	3600-6300
>50,000-2800	revised to	4050-7900
28,000	revised to	1700-6300
26,000	revised to	3560
23,600-5800	revised to	1650-3850
60,000-22,600	revised to	3550

MOLECULAR CLOCKS

Ayala F J. 1986. On the virtues and pitfalls of the molecular evolutionary clock. Journal of Heredity 77:226-235.

Summary. According to evolutionary theory, comparisons of DNA and protein molecules should reveal the extent of evolutionary divergence between species. If most mutations are neutral, the rate of divergence should be relatively constant, especially when averaged over long periods of time. However, rates of evolution of different groups of molecules vary widely. A few sequences are known from organisms that range from closely related to very remotely related. One example is cytochrome c, which shows reasonably good clock-like behavior, despite some irregularities. Another example is the copper-zinc superoxide dismutase (SOD), which does not act like a good clock. More data sets are needed in order to determine which mode is more common. Until then, conclusions based on the accuracy of the molecular clock are to be viewed with caution.

Britten RJ. 1986. Rates of DNA sequence evolution differ between taxonomic groups. Science 231:1393-1398.

Summary. The mutation rates of DNA sequences during evolution can be estimated by comparing sequences in different species. This method is based on a belief that most point changes in DNA are selectively neutral. Time estimates are based on standard evolutionary interpretations from geology and paleontology. Divergence of DNA sequences can be estimated from measurements of the thermal stability of DNA duplexes formed between labeled DNA from one species and unlabeled DNA from a second species. Rates of sequence divergence are high for Drosophila, sea urchins, and rodents. Rates are low for anthropoid apes, and intermediate for prosimians. The high rates are about five times the lower rates. The rate of divergence has purportedly been reduced during primate evolution. Reduction of the rate is attributed to improvements in DNA replication or repair mechanisms in higher primates.

NATURAL SELECTION

Gould SJ. 1986. Of kiwi eggs and the Liberty Bell. Natural History 95(11):20-29.

Summary. The author, a leading authority in evolutionary thought, queries the peculiarities of the size of the kiwi egg. The kiwi, a flightless bird of New Zealand about the size of a hen, lays an egg that is about 25% of its body weight — an astounding and difficult task for the kiwi. Within an evolutionary context Gould rejects the "general strategy" of finding how this large-size egg benefits kiwis and thus results in survival. Instead he argues with supporting evidence that the small size of the kiwi compared to its egg represents a decrease in the size of the adult compared to its evolutionary ancestor. The argumentation is mainly from standard trends in relationship in egg size versus body size. However, benefit to the bird by the nutritional efficiency of a smaller-sized body is alluded to, making one wonder if this is complete emancipation from the "general strategy" mentioned above.

Comment. The significance of this paper lies in the presentation of a good case for degeneration instead of the usual progress approach to evolution. A different approach such as this lends support to the argumentation that evolutionary theory is so broad that most kinds of data can be fitted into it. It is thus beyond scientific evaluation.

Hsü KJ. 1986. Darwin's three mistakes. Geology 14:532-534.

Summary. Darwin's three mistakes were that

1. he dismissed mass extinctions as artifacts of an imperfect geologic record;
2. he assumed that species diversity, like individuals of a given species, tends to increase exponentially with time; and
3. he considered biotic interactions the major cause of species extinction.

Those mistakes led to the theory propounded in his book (*The Origin*), which has been adopted by many as the scientific basis of their social philosophies.

Hsü downplays the importance of natural selection, preferring collisions with extraterrestrial bodies as an explanation for species extinctions.

Seeley RH. 1986. Intense natural selection caused a rapid morphological transition in a living marine snail. Proceedings of the National Academy of Sciences (USA) 83:6897-6901.

Summary. The intertidal snail, *Littorina obtusata*, lives in New England. Shells collected in northern New England between 1871 and 1900 were high-spired with thin walls, whereas shells collected between 1982 and 1984 were low-spired with thick walls. The change in shell shape is attributed to selection by the predatory crab, *Carcinus maenas*, which expanded its range into northern New England about 1900. This study provides an example of rapid morphological change not involving speciation.

PALEONTOLOGY

Beardsley T. 1986. Fossil bird shakes evolutionary hypotheses. Nature 322:677.

Summary. This news note reports on the find of two crow-sized birds in the Triassic Dockum Formation in Texas. The significance of this is that this is estimated to be some 75 million years earlier than *Archeopteryx*, the classic part-reptile, part-bird assumed ancestor of more modern birds. The new fossil find is said to have more modern bird-like features than *Archeopteryx*, but also has several reptilian affinities.

PHILOSOPHY OF SCIENCE

Medawar P. 1986. The limits of science. Oxcord: Oxford University Press. 103 p.

> **_Summary._** This book is not at all what its title implies. It is basically an apology for science. This popular author has presented a well-written insight into scientific thinking including some downgrading of other systems of thought. The book is useful is gaining insights into the philosophical stance of a scientist with a naturalistic faith.

PHYLOGENY

Cartmill M. 1982. Assessing Tarsier affinities: is anatomical description phylogenetically neutral? Phylogenie et Paleobiogeographie. Geobios Special Memoir 6:279-287.

> **_Summary._** This article illustrates how thoroughly a prevailing paradigm can permeate even a simple descriptive process such as anatomy. Three principal schools of thought concerning the assumed phylogenetic (evolutionary relationships) of the monkey-like Tarsier mammals are discussed. Interestingly, all three schools of thought use the anatomy of the ear to support their particular hypothesis. The article points out that anatomical terminology can incorporate phylogenetic bias. From the abstract:
>
> > *Describing the ear region in different terms yields different phylogenetic reconstructions, because each terminology defines a unique morphological space in which the morphologies of various primates assume different configurations connected by different minimal paths. It is probably not possible to eliminate phylogenetic bias from the analysis of complex anatomical features.*

SEDIMENT SOURCE

Drewery S, Cliff RA, Leeder MR. 1987. Provenance of Carboniferous sandstones from U-Pb dating of detrital zircons. Nature 325:50-53.

> **_Summary._** This paper discusses the origin of some of the massive (up to 5 km thick) Carboniferous sedimentary deposits in western Europe. The paper favors a simple direct source from the Precambrian (Archean) to the north without going through much of the recycling one would expect during the assumed extended Proterozoic and early Paleozoic times.
>
> **_Comment._** Such data fit well with the concept of a single world catastrophe.

SPECIATION

Chesser RK, Baker RJ. 1986. On factors affecting the fixation of chromosomal rearrangements and neutral genes: computer simulations. Evolution 40:625-632.

> ***Summary.*** Computer simulation models were used to determine which factors are favorable for the stochastic (random) fixation of chromosomal mutations within small isolated populations. Results indicate that the conditions important to fixation are: small founder (beginning) population (5 or 10), low interference with fertility, and numerous offspring. Random processes are not adequate to explain fixation if populations are greater than about 20, if fertility is substantially reduced, or if the number of offspring is low. When population size is reduced to 5 or 10 individuals, the extinction rate may exceed 40% or 30%, respectively.

Mayr E. Uncertainty in science: is the giant panda a bear or a raccoon? Nature 323:769-771.

> ***Summary.*** The taxonomic status of the giant panda has been controversial. Is it more closely related to the lesser panda or to the bears? It was originally described as a bear, but almost immediately placed with the raccoons and lesser panda. Several lines of evidence seem to favor the giant panda as a bear. These include anatomical, paleontological, chromosomal, and molecular studies. However, the giant panda and lesser panda do show certain similarities. These include their present distribution, their feeding behavior, and their hemoglobins. Mayr argues that their distributions may be explained as the result of historical accident and their feeding similarities may be due to similar diets. Further, according to Mayr, similar hemoglobins may be the result of convergence due to similar selective pressures, or may be the result of a recent change in the main group of bears. More data are needed, specifically the hemoglobins present in the South American spectacled bear and in the various members of the raccoon family.
>
> ***Comment.*** Mayr argues that selective pressures on hemoglobin have been conservative in the case of man and chimpanzee, “but in the case of the bears it might well have been centrifugal [diversifying].” The plasticity of this logic is pointed out in a letter by G. W. Warr (Nature 324:508), who states that “faith in natural selection alone can explain all in these sermons from the pulpit of neo-darwinism.” Warr’s comment is illustrative of the intensity of the present debate concerning the importance of selection in evolution.

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

A SCIENTIST'S ATTEMPT TO PLAY THEOLOGIAN

IN THE BEGINNING.... 1981. Isaac Asimov. NY: Crown Publishers, Inc. 234 p.

Reviewed by Jerry Bergman, Montpelier, Ohio

Isaac Asimov, probably the best-known science fiction writer today, has produced over 300 fiction and non-fiction books on almost every area of science and literature. Asimov's writing talents are legend, running the topical gamut from *Still More Lecherous Limericks* (for sale only to adults over 21) to *Guide to the Bible* (2 volumes). In addition to being prodigious, his writings are engaging and concise.

In the Beginning was written for the high-school or undergraduate-level reader. It is readable and flowing, although at times somewhat condescending to religious persons. *In the Beginning* is a verse-by-verse commentary of Genesis and, although it contains much good information, it is unfortunately rather superficial. No references or bibliography are given.

Asimov accepts uncritically the assumptions and conclusions of liberal scholars as, for example, the idea that the Pentateuch is a scissors-and-paste job of materials from four separate sources. He presents this "JEPD theory" without ever acknowledging the many criticisms against it. For example, the Religion section of *Time* (December 7, 1981) reported that a five-year computer study found that Genesis is more likely the work of a single writer and that the JEPD theory, which has hardened into liberal orthodoxy, must be "rejected or at best thoroughly revised." This conclusion came from Yehuda Radday of Haifa's Israel Institute of Technology who, according to *Time*, earned wide acclaim for his computer analysis of other books of the Bible — Judges, Zechariah, and Isaiah. Asimov should acknowledge such studies.

The tone of Asimov's book is set on the first page with such statements as "Against these strong, unwavering and undeviating beliefs [referring to those who accept the Bible as God's Word], the slowly developing views of scientists have always had to fight." This superficial oversimplification evidences little knowledge of the history of science. Sometimes Asimov is misleading. In his introduction he describes the purpose of his book:

> *[It] does not argue one way or the other. It offers no polemics. It merely considers the verses of the Bible, line by line and, indeed, word by word, discusses the content and meaning, and compares them with the scientific view that pertains to the passage* (p 1-2).

As Asimov later admits, however, his book does no such thing. Rather than being objective and unbiased as the above statement promises, his purpose seems clearly to be persuasion of his readers that, though having historical value, the Bible merely reflects the unscientific beliefs of the ancient Hebrews.

Yet, Asimov praises the Genesis account:

> *... the Biblical writers ... labored to produce something that was as reasonable and as useful as possible. In doing so, they succeeded wonderfully. There is no version of primeval history, preceding the discoveries of modern science, that is as rational and as inspiring as that of the first eleven chapters of the Book of Genesis* (p 3).

One interesting comparison Asimov notes is that the Scriptures teach that the earth was at one time “without form and void” (disordered) which corresponds, interestingly, with the modern theory that the solar system was formed from a vast cloud of dust and gas. As another example: whereas most scientists formerly believed that the universe has always existed, Asimov points out that most scientists now believe that the universe had a definite beginning as the Bible states. He immediately dismisses this point of agreement as being superficial and trivial, given the discrepancy in attitudes towards the age of the earth (p 10).

He acknowledges that while religionists have had their squabbles over interpretation of the Bible and religious points, likewise science too has seen its share of arguments, disputes and polemics. A difference, Asimov insists, is that scientific opinion eventually swings one way or the other according to the “*compelling* evidence” (p 8), but religious opinion does not. This claim is simply not true. Right or wrong, some large religious denominations have moved radically away from their original emphasis. Many people of science would also beg to differ with his differentiation; we are still arguing some old “scientific” controversies (as anyone who has spent much time in science is well aware) and many religious controversies have been settled long ago. Paul, Peter and the apostles settled many of these centuries ago — how many Christians today argue about whether circumcision is a condition of salvation? Asimov's statements may be more true in physics and chemistry, but are by no means true for the other sciences. According to Kline (1981), in some sciences there are more debates today than ever before.

Other reviewers have also noted Asimov's evident lack of biblical knowledge. Gordon Stein (1981), writing in *The American Rationalist* 26(3):47, states:

> *Asimov brings a broad breadth of scientific knowledge to his examination of Genesis. How great his biblical knowledge is, one never can be quite sure. He does seem quite positive about many of his interpretations of the biblical text, even when theologians have been arguing among themselves over the meaning for years.*

Asimov recounts how the view that outside intervention was needed to account for the universe has been slowly discarded in science:

> *Scientists grew increasingly reluctant to suppose that the workings of the laws of nature were ever interfered with.... In short, the scientific view sees the Universe as following its own rules blindly, without either interference or direction* (p 11).

He adds the rather sweeping and highly debatable conclusion that "So far, scientists have not uncovered any evidence that would hint that the workings of the universe require the action of a divine being." He admits, though, that "On the other hand, scientists have uncovered no evidence that indicates that a divine being does not exist" (p 11-12).

Asimov also rehashes some of the old debates, i.e., God as the answer to where the universe came from causes him to ask, "Who made God?" Asimov does accurately describe the chief conflict between creationists and the evolutionists, namely:

> *The Bible describes a Universe created by God, maintained by him, and intimately and constantly directed by him, while science describes a Universe in which it is not necessary to postulate the existence of God at all* (p 13).

Asimov is rather dogmatic in many of his interpretations of *both* Scripture and science. For example, he is sure that "the heavens" (Genesis 1:11) refer to "the vault of the sky and the permanent objects within it" (p 14) and, further, that this vault is a solid, semi-circular dome covering the Earth. One might wonder how he could be so sure about this interpretation, especially in view of the fact that many Bible scholars have come to other conclusions.

He also indulges in much fanciful speculation. He describes a scenario in which the cosmic egg (a single body of matter, often described as about the size of a pin head that existed in the “beginning” and from which all that exists came from):

> *... explodes in the largest conceivable explosion (the ‘big bang’), and its fragments are at first entirely too hot for matter, as we know it, to exist. Initially, the products formed in the explosion are energy. In tiny fractions of a second, the temperature dropped precipitously, and the Universe became cool enough to form certain fundamental particles of matter. Today, however, the Universe is too cool to allow these particles to exist.*
>
> *A full second after the big bang, the temperature of the Universe had dropped to ten billion degrees, about what it is at the center of the largest stars, and the ordinary subatomic particles we know today came into existence. Later, ordinary atoms formed* (p 23).

This information, although presented as factual science, is pure speculation based on our current limited knowledge, much assumption and also, some might add, extremely fanciful speculation. There is nothing wrong with speculation. It serves an important part of doing science, but it should be clearly labeled as such. Asimov fails to do this. He is also evidently unaware of the difficulties of arriving at “truth” from the scientific method (Robbins 1978, Bergman 1983).

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GENERAL SCIENCE NOTES

PROBABILITY AND ITS APPLICATION TO THE ORIGIN OF LIFE

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Loma Linda University

WHAT THIS ARTICLE IS ABOUT

Probability theory has been developed and verified using physical devices such as coins or cards that meet the assumptions of fairness and independence inherent in probability theory. Because these assumptions may not apply to steps postulated in a scenario for the origin of life and because some of the steps may be nearly unique, probabilistic arguments regarding the origin of life do not seem to be applicable except as gross generalizations.

In this article the author quotes non-creationist scientists who suggest that time, space, and raw materials in the universe may be too limited to permit the origin of life by chance alone.

Probability is a mathematical construct that can be demonstrated to model well-behaved non-deterministic phenomena such as coin tosses, and is accepted as being useful in modeling and analyzing masses of data from well-designed scientific studies of less well-behaved random processes. The application of probability analysis to events which may be nearly unique and happen so seldom as to be rarely observed seems questionable from a practical viewpoint.

Probability is essential in comparing or predicting the outcome of events based on a particular model. In the case of the origin of life suitable models amenable to scientific investigations have not yet been proposed or evaluated.

The ability to foretell the future and to know and understand the past has been coveted by man for a long time. This is illustrated by the TV serial Star Trek fictional character Mr. Spock, who could state the probability of a unique, future event with great precision. Of course, the script invested Spock with an aura of authority as Chief Science Information Officer and assigned him superhuman mental abilities because of his “race.”

In the real world we are faced with unique past or future events to which we would like to assign probabilities because, even though in a scientific sense we do not “know” the truth about the matter, we want to talk about it with a degree of certainty and to discover incontrovertible evidence, if possible.

This note looks at some basic properties of probability and considers the appropriateness of using probability to demonstrate the impossibility or inevitability of the origin of life.

What is probability? and what do we mean by the term? are philosophical questions to which no clear or entirely satisfactory answers have been proposed (Theobald 1968). The frequency theory of probability is popular among many scientists and some philosophers. This theory defines probability objectively in terms of the frequency of occurrences in long runs. The advantage is that the definition is at the same time its measure (Theobald 1968).

Probability is a complex mathematical topic (Feller 1968, 1971; de Finetti 1974; Noether 1974). One way to define probability is with three axioms:

$$(1)\ P(A) \geq 0,\ (2)\ P(S) = 1, \text{ and } (3)\ P(A+B) = P(A) + P(B), \text{ if } AB = 0.$$

Statement (1) tells us that no probability can be negative; P(A) means the probability that the event “A” will occur; if P(A) = 0, “A” will not occur.

In statement (2), P(S) means the probability of the occurrence of the entire set of events or outcomes that can occur for a particular situation; for instance, when a coin is tossed the possible outcomes are “heads” or “tails”; other possibilities such as landing on its edge or disappearing are ignored; the biggest value that probability can take is 1 which is certainty. In statement (3), P(A+B) is the probability that 2 disjoint events will occur and indicates that this is the sum of the individual probabilities; by disjoint we mean that either “A” or “B” occurs and not some fractional happening of “A” and “B” simultaneously.

Because these are mathematical axioms, there is no point in talking about their “true nature” or “definition”; these are like the set of rules which define a game of chess (Feller 1968).

Not all events in the real world need to be treated probabilistically. Some phenomena always produce the same deterministic outcome under specified identical conditions. An illustration is the way an object falls to the ground with constant acceleration due to the force of gravity. Thus constant, static conditions yield a result which can be predicted with a great degree of certainty for a deterministic process.

In contrast are nondeterministic or random events where repeated observation under constant static conditions do not always lead to the same outcome. A popular example is the result of a coin toss. Consider a coin that is tossed many times. Heads or tails result in a seemingly erratic and unpredictable manner. Many such nondeterministic phenomena show a statistical regularity based on the concept of probability. By statistical regularity we mean that the outcome of a suitably large number of observations of a non-deterministic phenomenon can be predicted accurately before the observations are made if the statistics of the phenomenon are known. This means that a model has been proposed for the phenomenon and that the model has been tested, accepted, and is known to explain the situation adequately.

In the simple coin toss certain assumptions are inherent in the probabilistic interpretation. First, the coin must be fair so there is an equal opportunity for each outcome, heads or tails in this case, to occur at each toss. This means that the coin is not unbalanced, double headed, or biased in any way. Most recently minted, unaltered coins will be fair because of manufacturing procedures.

Second, the coin is independent of its past. It has no memory of its past outcomes, and the past cannot influence the outcome of the current toss. For example, the probability of a head on any coin toss is 0.5. If a series of 10 heads in a row has been tossed for a coin, then for the 11th toss the probability of heads is still 0.5; the coin has not run up a deficit of tails which it is obligated to repay.

The assumptions of fairness and independence have been realized in other nondeterministic phenomena used to investigate probability. Examples are containers with fixed numbers of distinguishable but identical objects such as an urn with red or black balls or gambling devices such as cards or a roulette wheel.

There is a considerable gap between simple cases such as the coin toss and situations which are important in the real world. Again the assumptions of fairness and independence are important, but the assumptions may be compromised or ignored. Examples would be life insurance, risk management, and the interpretations of the results of scientific experiments.

An important reason why these results can be evaluated probabilistically is that there is a sufficient number of instances under consideration so that analysis is possible. In a statistical sense we would say that the sample size is large enough. How large is large enough is the subject of controversy, but usually it is on the order of 25 or 100.

In the analysis of the results of scientific experiments, one cannot use statistics if the number of occurrences under consideration is too small, because there is a direct relationship between the sample size and one’s confidence in the interpretation of the outcome. Statistical theory tends to impose this limitation on us. As a consequence we really know little about using statistical theory and methods to evaluate the probability of unique events.

Two important concepts are directly involved with the application of probability to the origin of life. These are RANDOMNESS and IMPOSSIBILITY, concepts that are intuitively understood but for which concrete definitions are difficult to find.

Knuth (1969) in his monumental 3-volume series, *The Art of Computer Programming,* devotes 160 pages to his treatment of the generation of pseudorandom numbers by a computer and to the evaluation of such techniques, Certain tests can be applied to a series of numbers to determine if the series meets the criterion of randomness. Even in a series of statistically acceptable random numbers, a non-random pattern may be detected.

The point he makes is that it is not always easy to distinguish between random and non-random even under ideal conditions.

Impossibility is another relative term. Borel (1962) discusses probabilities that are negligible on 4 different scales. On the human scale events rarer than one in a million are essentially ignored. On the terrestrial scale he suggests that one in 10^{15} is negligible, since this is about a billion times as small as the probability ignored by one man. On the cosmic scale he sets one in 10^{50} as being either impossible or at least would never be observed. On the supercosmic scale he uses a number on the order of one in 10^{n}, where n is a number of more than 10 figures.

Consider the following situation. Using current actuarial practice, what is the probability that a man can live to be 1000 years old? According to formulas on which modern mortality tables are based, the proportion of men surviving 1000 years is of the order of magnitude of one in $10^{**}10^{35}$ (10 to the 10th power to the 35th power). This statement makes no sense from a biological or sociological point of view, but considered exclusively from statistical considerations it certainly does not contradict any experience. Since fewer than 10^{10} people are born in a century, it would require $10^{**}10^{35}$ centuries to test the contention statistically which is $10^{**}10^{34}$ times the supposed lifetime of the earth. Such small probabilities are compatible with our notion of impossibility (Feller 1968).

Another example of a small probability involves the following argument proposed to show that a pattern is needed to make a biologically active enzyme (Pardee 1962). This argument was proposed before it was known that protein molecules could contain subunits; however, the enzyme prokaryotic DNA I polymerase is a single polypeptide chain with MW = 110,000 (White et al. 1978).

Suppose we consider a protein of molecular weight 100,000 which is composed of 830 amino acids in a particular order. The number of possible ways that 830 amino acids can be arranged to form a protein of this size is 20^{830}. A sphere constructed from one of each of these 20^{830} molecules would have a radius of 10^{345} light years (Pardee 1962). The visible universe has a diameter of about 10^{12} light years.

How should one approach the problem of using very small probabilities to bolster the concept of the apparent impossibility of the origin of life from non-living sources? At the present time the theory involves the spontaneous union of amino acids to form postulated prebiologically significant proteins, given the necessary precursor amino conditions. Does this really establish the impossibility of abiogenesis? We do not know the exact conditions that may have prevailed. Considering this from a purely probabilistic viewpoint we do not know that the growth or breakup of a polypeptide or other macromolecule was strictly random or that some type of autocatalysis would mean the process was not random; this might make certain sequences of amino acids more probable or it might make biologically desirable sequences less probable.

The difficulties of actually applying probability to the events postulated by some to have occurred in the origin of life have been noticed previously. The following notes from S. W. Fox (ed.), 1965, *The Origins of Prebiological Systems and of Their Molecular Matrices*, will support this contention. I have selected passages that are especially interesting to me; I am not trying to make a statement about the philosophy or beliefs of the particular author.

J. B. S. Haldane in his paper, "Data Needed for a Blueprint of the First Organism," postulates a very primitive kind of "organism" and makes the following statement:

> *If the minimal organism involves not only the code for its one or more proteins, but also twenty types of soluble RNA, one for each amino acid, and the equivalent of ribosomal RNA, our descendants may be able to make one, but we must give up the idea that such an organism could have been produced in the past except by a similar pre-existing organism or by an agent, natural or supernatural, at least as intelligent as ourselves, and with a good deal more knowledge* (p 12).

Haldane suggests that something like a generalized phosphokinase may have been involved which may have contained about 25 amino residues. In talking about the generation of such a molecule from existing amino acids, he states:

> *But even this would mean one out of 1.3×10^{30} possibilities. This is an unacceptable, large number. If a new organism were tried out every minute for 10^8 years, we should need 10^{17} simultaneous trials to get the right result by chance. The earth's surface is 5×10^{18} cm^2. There just isn't, in my opinion, room. Sixty bits, or about 15 amino acids, would be more acceptable probabilistically, but less so biochemically* (p 14).

Peter T. Mora in his paper, "The Folly of Probability," points out some problems and limitations inherent in present-day science when trying to account for the origin of life. I quote the following as an example of his statements:

> *A further aspect I should like to discuss is what I call the practice to avoid facing the conclusion that the probability of a self-reproducing state is zero. This is what we must conclude from classical quantum mechanical principles, as Wigner demonstrated....These escape clauses postulate an almost infinite amount of time and an almost infinite amount of material (monomers), so that even the most unlikely event could have happened This is to invoke probability and statistical considerations when such considerations are meaningless. When for practical purposes the condition of infinite time and matter has to be invoked, the concept of probability is annulled. By such logic we can prove anything, such as that no matter how complex, everything will repeat itself, exactly and innumerably* (p 45).

In the discussion following Mora's paper, Carl Sagan takes Mora to task for suggesting that 5 billion years is an infinite period of time. Mora replies, "That is a matter of opinion" (p 60).

J. D. Bernal comments:

> *In the first place, the questions may be wrongly put; such a question, for instance, as 'could life have originated by a chance occurrence of atoms' clearly leads as our knowledge, and also the limitations of the time and space available, increase, to a negative answer* (p 52-53).

H. H. Pattee makes some comments concerning probability:

> *The concept of probability I don't believe is properly used here, at least the way Laplace and others represent it. The idea is that two models which are sufficiently well defined in order to apply a probability measure may then be objectively compared with probability theory, which is only a mathematical theory. In this sense, probability cannot possibly explain anything. It is an objective way to compare two alternative models. And in this sense, I don't believe it is folly to use probability* (p 58).

Other remarks by Pattee include:

> *I think we agree that the chance hypothesis for the origin of life is unsatisfactory. It is not only conceptually barren, but also untestable empirically. However, if we create an alternative model which is sufficiently well defined to apply probability theory, it may then be correctly applied. It is not the fault of probability theory that a good model hasn't been made yet* (p 58).

A Szutka suggests that more than chance was responsible for events leading to living systems. He mentions the possibility of several (unknown) parameters acting and increasing the probability that the event would occur (p 60). In terms of our previous discussion this means that the two or more molecules are not independent, and therefore it is going to be difficult to apply probability measures to such an instance.

Mora's response is:

> *I hope I don't give the impression that by pure chance it [the origin of life] could have happened just by itself, without there being some particular yet unknown attributes or physicochemical properties in the interacting molecules* (p 60).

In conclusion, probability is a mathematical construct which can be demonstrated to model well-behaved non-deterministic phenomena such as the results of coin tosses and is accepted as being useful in modeling and analyzing masses of data from well-designed scientific studies of less well-behaved random processes. The application of probability analysis to events which may be nearly unique and happen so seldom as to be rarely observed seems questionable from a biological point of view. Forgetting about problems of bias and independence which are inherent in the discussion, some scientists other than creationists agree that the appearance of life through the sole action of random events on molecules is so excessively close to being impossible that other, possibly supplemental, explanations must be sought.

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