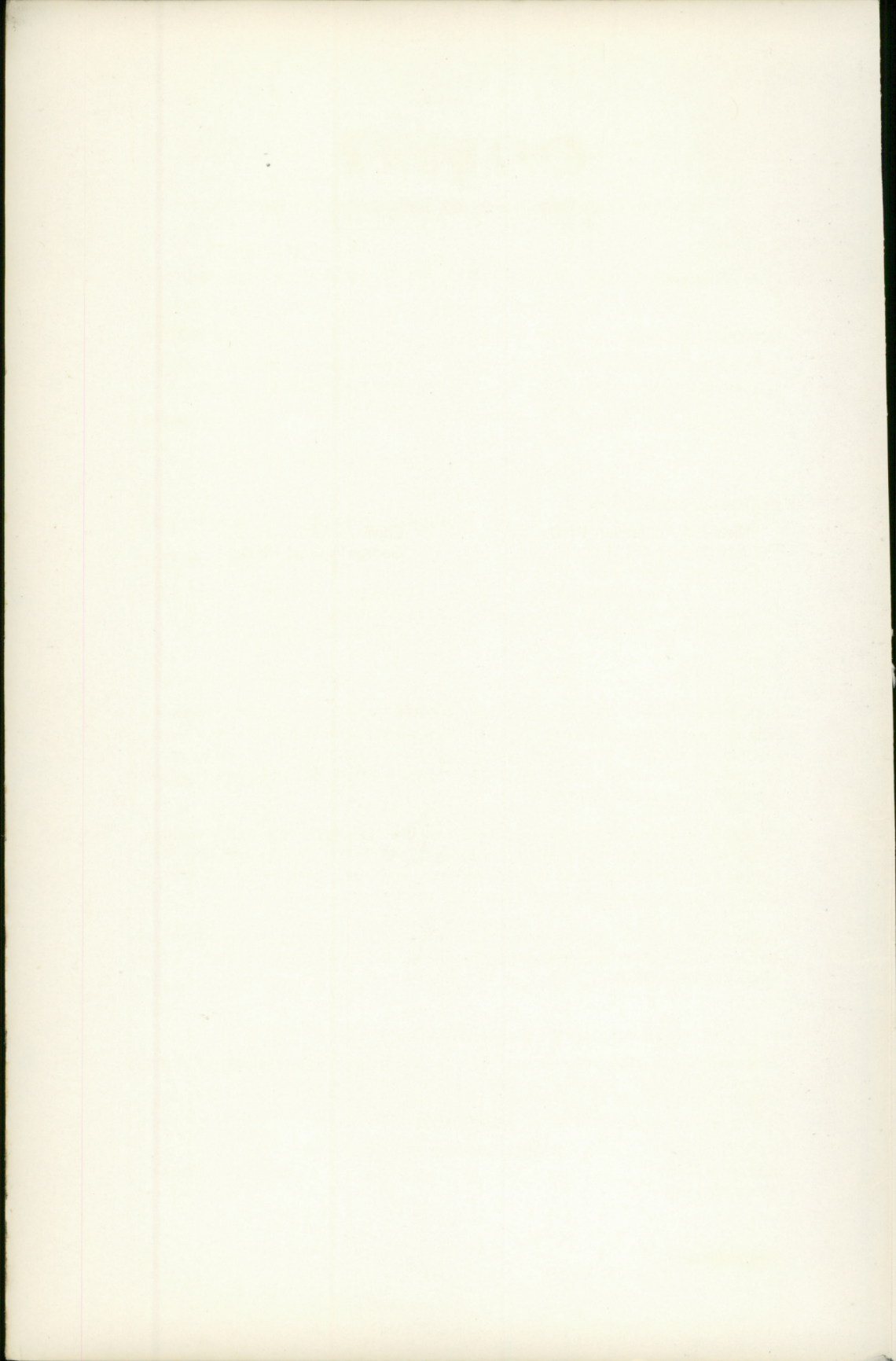


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Coal seams in the Cretaceous Star Point Sandstone north of Price, Utah. The article by Paul Giem discusses the possible implications of radiocarbon dates of less than 100,000 years that have been found in some coals. Photographs courtesy of Clyde L. Webster.

ORIGINS welcomes original manuscripts on topics related to an understanding of earth history from a creationist viewpoint. The ideas presented are not necessarily those of the Geoscience Research Institute.

ANNOUNCEMENT

Please note the change in numbering of *Origins*, beginning with this issue. Volume numbers will no longer be used. This issue of *Origins* is the 51st to be published, and is numbered accordingly; and the year of publication will now reflect the actual year in which the issue is printed. The new system is designed to prevent the confusion that arose when different parts of a volume were published in different years.

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EDITORIAL

RIVERS OUT OF EDEN

Richard Dawkins recently wrote a book entitled River Out of Eden: A Darwinian View of Life,¹ in which he compared the river of Eden with the flow of digital information in DNA. From the point of the origin of life, this information has flowed from ancestor to descendant. Like Eden's river, the flow has divided repeatedly, forming today's biodiversity. I found Dawkins' metaphor interesting, although probably not in the way he intended.

One of the criticisms of the Genesis creation account has been the way the river is described. According to Genesis 2:10, a river flowed out of Eden and divided to produce four smaller rivers. Ordinary rivers don't do that. Instead, tributaries flow together to form larger rivers. Thus, something is wrong with the description of a river that divides as it flows.

But what about canal systems? Canal systems do indeed divide to provide water to different points along the route. Evidently, the "river" out of Eden was more like a canal than a river. And canals are designed. That is the point I found particularly interesting about Dawkins' book title. As Eden's river was the result of design, so the digital information in DNA has the characteristics of design.

The design evident in living organisms has not escaped Dawkins' notice. He states: "The illusion of purpose is so powerful that biologists themselves use the assumption of good design as a working tool" (p 98). The Darwinian philosopher Michael Ruse has also noted the usefulness of the concepts of design and purpose in biology: "Organisms, unlike planets and particles, really do look as if they were designed."² Not being predisposed to reject the idea of design, I will simply accept the obvious and return to the river metaphor.

If one views the fossil record as Dawkins does — as a process of branching over hundreds of millions of years —, one finds an anomaly with respect to the metaphor of a branching river. When we first view the "river" in the Cambrian sediments and uppermost Precambrian, we find not one "river," but many separate "rivers." A large proportion of Phyla and Classes are found in Cambrian

sediments, or are inferred to have been present.⁴ The well-known "top-down" pattern of the fossil sequence suggests, not one river, but many rivers with separate sources. Even at lower taxonomic levels the systematic pattern of morphological gaps among the fossils suggests that additional independent lineages abruptly appear throughout the fossil record.

Creationist theory offers an interesting hypothesis to explain the observed pattern of the discontinuity of life. Many lineages were created separately. This does not deny descent with modification, but it does recognize that modification requires a preexisting starting point. The origins of "morphological novelties" remain unexplained except as a result of separately created starting points.

In creationist terminology, the term baramin is used to refer to a separately created pair or group.⁵ From each separately created baramin, a "river" of information for life, contained in the DNA, has flowed to its descendants. Each baramin can be considered a separate river. Since life consists of many separate lineages, we can describe them, as in our title, as many "rivers out of Eden."

ENDNOTES

1. Dawkins R. 1995. River out of Eden: a Darwinian view of life. NY: Basic Books.
2. Ruse M. 1989. Teleology in biology: is it a cause for concern? Trends in Ecology and Evolution 4:51-54.
3. DeHaan RF. 1998. Do phyletic lineages evolve from the bottom up or develop from the top down? Perspectives on Science and Christian Faith 50:260-271.
4. E.g., see: (a) Valentine JW. 1995. Why no new phyla after the Cambrian? Genome and ecospace hypotheses revisited. Palaios 10:190-194; (b) Wray GA, Levinton JS, Shapiro LH. 1996. Molecular evidence for deep Precambrian divergence among metazoan phyla. Science 274:568-573.
5. The term was first introduced by Frank L. Marsh in 1941 (Fundamental biology. Lincoln, NE: self-published, p 100). For a recent discussion of the term, see: ReMine WJ. 1993. The biotic message. St Paul MN: St Paul Science, p 443-453.

ARTICLES

CARBON-14 CONTENT OF FOSSIL CARBON

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WHAT THIS ARTICLE IS ABOUT

This article reviews the theoretical basis for expecting the presence of carbon-14 in Pliocene to Cambrian carbon from certain creationist viewpoints, and for expecting its absence from a viewpoint proposing a long age of life on Earth. The relevant experiments are discussed. Several conclusions emerge: 1) There is measurable carbon-14 in material that should be "dead" according to standard evolutionary theory; 2) machine error can be eliminated as an explanation for this carbon-14 on experimental grounds; 3) nuclear synthesis of this carbon-14 in situ can be eliminated on theoretical grounds; 4) contamination of fossil material in situ is unlikely but theoretically possible, and is a testable hypothesis; 5) contamination during sample preparation is a significant problem but theoretically soluble; 6) residual activity is most likely indicated by the present data, and if correct, would eliminate an age greater than approximately 100,000 years for life on Earth; and 7) additional experimental evidence cannot eliminate either a short or a long age of life on Earth, but can provide evidence tending to discriminate between the two.

CLASSIFICATION OF MAJOR THEORIES OF EARTH HISTORY

This paper deals with the presence of carbon-14 in fossil material and its implications for theories of the age of life on Earth.¹ For our purposes these theories can be divided into roughly three categories:

- (a) Theories which assume that life has been on Earth for 1-4 billion years include mechanistic evolution, theistic evolution, multiple creations/progressive creation, and ruin-and-restoration theories.
- (b) Theories which assume that life has been on Earth for less than 100,000 years and that radiometric decay constants have remained constant during that time include various forms of

special creationism. These include those placing the Flood at the time indicated by the Masoretic text of Genesis 11 (4,300-4,500 years ago), those dating the Flood by the Septuagint (5,500 years ago), and those placing the Flood at a somewhat more remote time (usually about 10,000-20,000 years ago).

- (c) Theories assuming that life has been on Earth for less than 100,000 years and that radiometric decay constants have not remained constant during that time include various forms of special creationism which may be quite similar to those mentioned in the second category, except for their view regarding decay constants.²

The predictions of the third category of theories regarding carbon-14 in fossil carbon (carbon from such sources as coal, oil, natural gas, wood, or bone) usually match those of the first category, although they are not logically required to do so. In fact, unless there are some constraints on how much radiometric constants may vary, the third category of theories cannot make any predictions whatever. In this paper we are concerned with theoretical predictions and their match with experimental evidence. Since the third category has difficulty making any predictions regarding carbon-14 in fossil carbon, it will be ignored here, not because we know it to be wrong, but because it is untestable.

LONG-AGE THEORIES PREDICT NO CARBON-14 IN GEOLOGICALLY OLD SAMPLES

In the first category — long-age theories —, some rather definite predictions can be made about samples that are assigned an age greater than 100,000 years. No one assumes that the concentration of carbon-14 in ordinary carbon ($^{14}\text{C}/\text{C}$ ratio) in the biosphere has ever been more than 10x the present $^{14}\text{C}/\text{C}$ ratio. One can accordingly establish a reasonable upper limit of 0.0056 percent modern carbon (pmc) for the $^{14}\text{C}/\text{C}$ ratio in a 100,000-year-old specimen. Every 57,100 years the $^{14}\text{C}/\text{C}$ ratio decreases by a factor of 1,000. A 200,000-year-old specimen should have a present $^{14}\text{C}/\text{C}$ ratio of 0.000 000 031 pmc or less. By the time we get back to 300,000 years, a sample should have less than one atom of carbon-14 in a gram of carbon as residual activity.³ This means that 1 million-year-old samples, or 350 million-year-old samples, should have **no** residual radiocarbon.

Explanations of measured radiocarbon in an old sample that are consistent with long-age theories might include carbon-14 created there by nuclear synthesis, carbon-14 from elsewhere contaminating the sample (either in the ground or during sample preparation), or machine error (the measuring device indicating the presence of carbon-14 in the sample when in fact there is none). These possible sources of error will be discussed below.

MOST SHORT-AGE CONSTANT-DECAY MODELS PREDICT A SMALL AMOUNT OF CARBON-14 (0.6 TO 0.005 PMC) IN GEOLOGICALLY OLD SAMPLES

The predictions of the second category of theories, which we shall call short-age constant-decay theories, are not as clear-cut. There is general agreement among short-age theories that the Paleozoic and Mesozoic sediments were deposited by the Flood, and are thus contemporaneous. Some would have sediments up to the Pliocene also deposited by the Flood, while others would have the Pliocene and possibly other Cenozoic sediments be immediately post-Flood. The date of the Flood would vary from theory to theory, although usually by less than 20,000 years). In addition, there are questions about how much carbon-14 was in the earth at Creation, how much carbon-14 was being formed per year before the Flood, and how much ordinary carbon was in the biosphere at the time the Flood started.

With the simplest case, we will assume that Earth was created in equilibrium with respect to carbon-14, and that the cosmic ray flux, Earth's magnetic field, and distribution of nitrogen in the atmosphere before the Flood were all essentially the same as today. Then we can assume that the amount of carbon-14 in the biosphere was the same as it is today. A short-age Flood model requires that this carbon-14 would have been diluted in a pool of ordinary carbon (carbon-12 and carbon-13) vastly greater than that of today. How much greater that pool was would be based on the amount of existing fossil carbon. Certainly the carbon from all the coal in Flood strata, probably all the oil and possibly the natural gas,⁴ and an unknown percentage of all the limestone would have been in the biosphere. Fossil shells should have been in the biosphere, but there could have been a reservoir effect so that they would have less carbon-14 than expected. Amorphous or crystalline calcium carbonate may or may not have been in equilibrium with the biosphere.

Therefore, to find the pre-Flood pool of ordinary carbon, one would need to add all the coal, oil, and possibly natural gas reserves, and some percentage of the world deposits of limestone. The $^{14}\text{C}/\text{C}$ ratio expected before the Flood would then be the present one divided by the ratio of fossil carbon to carbon in the biosphere.

The best estimates I have seen for carbon in various reserves were collected by Brown (1979). More recent estimates (for example, Scharpenseel and Becker-Heidmann 1992) agree within a factor of 2. Brown's estimate for carbon in the modern biosphere was 3.9×10^{13} metric tons, for fossil organic carbon 6.8×10^{15} metric tons, and for sedimentary carbonate 1.3×10^{16} metric tons. Accordingly, the pre-Flood reservoir of ordinary carbon would have been some 180-510x as much as at present. This estimate could easily be in error by a factor of 2 or so in either direction. This would affect the denominator of the $^{14}\text{C}/\text{C}$ ratio and thus decrease this ratio in the pre-Flood era by some 200-500x and possibly up to 1000x compared to the modern era. Based on these considerations, my best estimate would be about 200x, but 100-400x seems reasonable.

The numerator of the $^{14}\text{C}/\text{C}$ ratio could also have been different before the Flood. Some of the factors that could reasonably affect the numerator are the cosmic ray flux and the amount of carbon-14 existing at the time of creation. If one assumes that at creation there was no carbon-14 in the biosphere, and that the Flood was 1656 years after creation (the shortest reasonable time), then at the time of the Flood carbon-14 would have built up in the biosphere to 18% of its equilibrium value, based on a constant production rate for carbon-14. In addition, if the magnetic field was at maximum reasonable strength, the production of carbon-14 would have been reduced by approximately 75% (Brown 1979). A stronger magnetic field would seem to be a very reasonable assumption. Finally, a vapor canopy might have reduced the production of carbon-14 by an unknown amount, although a physically stable vapor canopy would probably have had a minor effect that may be ignored for our purposes.

It is not unreasonable to postulate a very low, non-equilibrium total amount of carbon-14 in the original atmosphere. This is not likely to be explained by the theory that there was no carbon-14 immediately after creation because creation was perfect. That theory would imply that there were no other radioactive isotopes immediately after creation. Other radioactive isotopes such as potassium-40 are in the biosphere

now, and they were probably in the biosphere at the time of the Flood, and also at creation. However, if one assumes that Earth's matter existed before creation, there is the possibility that the primeval atmosphere contained primarily water vapor and was devoid of nitrogen, in which case the production of carbon-14 from cosmic rays would be markedly reduced. So a minimal concentration of carbon-14 at creation week cannot be ruled out.

Finally, time since the Flood must be factored into any model for carbon-14 dating. If one follows a Masoretic chronology, there would be a reduction in the carbon-14 in pre-Flood samples of 41-42% due to the time since the Flood. For a Septuagint chronology, the reduction would be about 50%, and for gap theories the reduction would be substantially larger. Putting the Flood at the date proposed by Aardsma (1991) — 12,000 B.C. — would reduce the amount of carbon-14 by 82%. Putting it at 57,100 years ago would reduce it by 99.9%. At this point I will ignore theories that place the Flood more than about 20,000 years ago (and would reduce the concentration of carbon-14 by >91%), although it must be acknowledged that these theories cannot be logically excluded from consideration.

The various factors that would reduce the pre-Flood $^{14}\text{C}/\text{C}$ ratio in the biosphere are not entirely independent of each other. One can propose a Flood at 20,000 years ago, but if one expands the post-Flood chronology, then it seems illogical to assume a short chronology for the time between creation and the Flood. Increasing the time between creation and the Flood provides more time for carbon-14 to equilibrate and lessens the apparent aging effect of starting with little or no carbon-14 at creation. Thus it is not accurate to take all the reduction factors and simply multiply them together. The same is true, although to a lesser degree, for models based on the Septuagint. Finally, if one assumes that some of the carbon in the Phanerozoic fossil record came from comets or meteorites, the reduction in the pre-Flood $^{14}\text{C}/\text{C}$ ratio caused by a larger pre-Flood biomass must be decreased by the proportion of "fossil" carbon that did not come from the earth.

We will now make some estimates using the above assumptions. For example, suppose we start with a Masoretic chronology, a stronger pre-Flood magnetic field, and a negligible amount of carbon-14 at Creation. Then a reasonable first approximation for the expected measured $^{14}\text{C}/\text{C}$ ratio of fossils buried in the Flood is the reduction due to biomass, multiplied by the reduction due to the magnetic field, multi-

plied by the reduction due to non-equilibrium conditions at the beginning, multiplied by the reduction due to the passage of time since the Flood. My best *a priori* estimate of the numbers would be $1/200 \times 1/4 \times 1/5 \times 60\%$, or $1/6,667$, which would correspond to 0.015 pmc measured. It could be as low as $1/4$ of that if our estimates of fossil carbon are low and the carbon in limestone was in equilibrium with the biosphere,⁵ although experimental evidence (see below) indicates that dolomite was not in equilibrium with the biosphere and suggests that most of the limestone was also not in equilibrium with the biosphere. A more likely lower limit would be $1/13,333$, or 0.0075 pmc. A reasonable upper limit would be $1/100$ (low estimate of reduction due to biomass) $\times 60\%$, or 0.6 pmc. Much of the spread in the upper limit is due to differences in assumptions regarding the pre-Flood magnetic field, assumptions that are presently untestable. A Septuagint chronology would predict roughly the same numbers. The decrease due to a longer time since the Flood would be almost exactly offset by an increase due to more time between creation and the Flood. The only change would be that the upper limit would drop to 0.5 pmc.

Ancient flood models probably should not use factors for non-equilibrium conditions before the Flood. Therefore the model proposed by Aardsma (1991) should predict a most likely concentration of $1/200 \times 1/4 \times 18\%$, or 0.0225, with a lower estimate of 0.01125 (or 0.01) pmc and an upper estimate of 0.18 pmc. At 21,000 years the estimate should be roughly 0.01 pmc with a lower limit of 0.005 pmc and an upper limit of 0.08 pmc. Calculations could be made for other models, but these calculations give one a feel for the predictions that can be expected from various models. It is of interest that there is so little variation in the predictions for the lower limit for present-day measurements of pre-Flood fossil carbon among the major models.

CARBON-14 IS FOUND CONSISTENTLY IN GEOLOGICALLY OLD SAMPLES

When carbon-14 dating was first developed, the level of carbon-14 was measured by counting the decay of carbon-14 atoms in a given sample (decay counting). This was associated with a high background count, which, under most circumstances, swamped the low levels of carbon-14 expected by short-age constant-decay theories noted above. It also necessitated having a control counter, which would be filled with

supposedly "dead" carbon. Any small residual amount of carbon-14 in the "dead" carbon would not be detected, because the method guarantees that any residual would be subtracted out. A possible exception would be if one used truly non-fossil carbon which was known to contain no residual carbon-14 for the comparison. As far as I know, such an experiment has never been reported, and it is difficult to imagine it being done by someone who did not consider short-age constant-decay theories a live option.

A method called isotope enrichment might be able to find carbon-14 in fossil material even given the above difficulties. This method involved concentrating the carbon-13 and carbon-14 in a specimen by fractional distillation of carbon monoxide. The fraction of carbon-14 in a specimen is increased, making it measurable using standard decay-counting techniques. This method could theoretically detect carbon-14 in geologically old specimens, since, for example, carbon dioxide from anthracite coal can be compared with enriched carbon dioxide from anthracite coal.

The experiment in question was done at least three times (Grootes et al., 1975). The first time, the results on anthracite were 0.023 ± 0.011 pmc. Grootes et al. believed that there was contamination in the system. They made some changes in the process and repeated the experiment two more times, getting 0.0072 ± 0.0096 pmc, and 0.0062 ± 0.0038 pmc. If the last two results are combined statistically, they give 0.0064 ± 0.0035 pmc, which is not statistically different from zero. This particular method has fallen out of favor. The reason for this is not documented in the literature, but probably was due at least in part to the fact that it involved a difficult, time-consuming fractional distillation followed by a time-consuming process of counting decays.

In the late 1970s a new method of measuring carbon-14, called AMS, or Accelerator Mass Spectrometry dating, was developed. This involved directly counting the carbon-14 atoms, using a tandem accelerator. Since the atoms are first negatively charged, most of the interference from nitrogen-14, which is much more common than carbon-14 but does not easily take a negative charge, is eliminated. In addition, each atom is accelerated by a very high voltage, and several tests can be done to make sure that we are in fact measuring carbon-14 instead of some interfering isobar, or cosmic rays. Theoretically, the machine should have zero machine background, which makes it ideal for attempting to detect carbon-14 in geologically old specimens.⁶

If one defines machine background as carbon-14 equivalent counts without a sample in place, the predictions of zero background turn out to be largely correct. Schmidt et al. (1987) were able to run their machine with an empty aluminum target holder without finding any atoms of carbon-14 in a 30-minute run, which would be equivalent to >90,000 radiocarbon years (<0.0014 pmc) if they had had a standard current of ordinary carbon. Van der Plicht et al. (1995) found an equivalent age of >100,000 radiocarbon years, and Kirner et al. (1995) obtained an equivalent age of >104,000 years.

Careful experimental technique is necessary. Some experiments did show small amounts of carbon-14 in the machine blanks. Donahue et al. (1984) found carbon-14 atoms equivalent to 0.08 pmc with an empty target holder. Kitagawa et al. (1993) obtained 0.03 pmc. Beukins et al. (1992) did better (0.015 ± 0.007 pmc). Apparently with more careful technique one can reduce the machine background to negligible levels, as noted in the preceding paragraph.

However, as one can see from Table 1 (p 14-15), carbon samples have not matched the best results from machine blanks. There is some residual carbon-14 in even the most carefully prepared samples, so that the article by Schmidt et al. was entitled "Early expectations of AMS: greater ages and tiny fractions. One failure? – one success." As can be seen from Table 1, further experiments have continued to find carbon-14 in supposedly "dead" carbon, raising the question as to how to explain this carbon-14.

Short-age constant-decay theories predict that fossil carbon should contain a small amount of carbon-14, and one explanation of the above data is that one of these short-age theories is correct. But there are other possible explanations. The obvious ones are machine background which only happens when carbon-12 and/or carbon-13 are in the machine, contamination of the source deposits in the ground (*in situ*), contamination of the samples with modern carbon during sample processing, or the creation of carbon-14 *in situ* by nuclear reactions.

MACHINE BACKGROUND IS NOT AN ADEQUATE EXPLANATION

The hypothesis that machine background can account for this carbon-14 has been universally rejected by researchers in the field, and for good reason. Any atom which is counted as carbon-14 must pass at least 3, and sometimes 4 tests. First, it must pass through the

TABLE 1
Radiocarbon Measurements on "Dead" Carbon

¹⁴ C/C ratio (pmc) (± 1 S.D.)	Material	Reference
0.71 ± ?*	Marble	Aerts-Bijma et al. 1997
0.61 ± 0.12	Foraminifera	Arnold et al. 1987
0.60 ± 0.04	Commercial graphite	Schmidt et al. 1987
0.52 ± 0.04	Whale bone	Jull et al. 1986
0.51 ± 0.08	Marble	Gulliksen & Thomsen 1992
0.5 ± ?	Dolomite (dirty)	Middleton et al. 1989
0.5 ± 0.1	Wood, 60 Ka	Gillespie & Hedges 1984
0.42 ± 0.03	Anthracite	Grootes et al. 1986
0.401 ± 0.084	Foraminifera (untreated)	Schleicher et al. 1998
0.383 ± 0.045	Wood (charred)	Snelling 1997
0.358 ± 0.033	Anthracite	Beukins et al. 1992
0.342 ± 0.037	Wood	Beukins et al. 1992
0.34 ± 0.11	Recycled graphite	Arnold et al. 1987
0.32 ± 0.06	Foraminifera	Gulliksen & Thomsen 1992
0.3 ± ?	Coke	Terrasi et al. 1990
0.3 ± ?	Coal	Schleicher et al. 1998
0.26 ± 0.02	Marble	Schmidt et al. 1987
0.2334 ± 0.061	Carbon powder	McNichol et al. 1995
0.211 ± 0.018	Fossil wood	Beukins 1990
0.21 ± 0.02	Marble	Schmidt et al. 1987
0.21 ± 0.06	CO ₂ (source?)	Grootes et al. 1986
0.20 - 0.35* (range)	Anthracite	Aerts-Bijma et al. 1997
0.2 ± 0.1*	Calcite	Donahue et al. 1997
0.198 ± 0.060	Carbon powder	McNichol et al. 1995
0.18 ± 0.05 (range?)	Marble	Van der Borg et al. 1997
0.18 ± 0.03	Whale bone	Gulliksen & Thomsen 1992
0.18 ± 0.03	Calcite	Gulliksen & Thomsen 1992
0.18 ± 0.01**	Anthracite	Nelson et al. 1986
0.18 ± ?	Recycled graphite	Van der Borg et al. 1997
0.17 ± 0.03	Natural gas	Gulliksen & Thomsen 1992
0.166 ± 0.008	Foraminifera (treated)	Schleicher et al. 1998
0.162 ± ?	Wood	Kirner et al. 1997
0.16 ± 0.03	Wood	Gulliksen & Thomsen 1992
0.154 ± ?**	Anthracite coal	Schmidt et al. 1987
0.152 ± 0.025	Wood	Beukins 1990
0.142 ± 0.023	Anthracite	Vogel et al. 1987
0.142 ± 0.028	CaC ₂ from coal	Gurfinkel 1987
0.14 ± 0.02	Marble	Schleicher et al. 1998
0.130 ± 0.009	Graphite	Gurfinkel 1987
0.128 ± 0.056	Graphite ("unknown provenance")	Vogel et al. 1987
0.125 ± 0.060	Calcite	Vogel et al. 1987
0.112 ± 0.057	Bituminous coal	Kitagawa et al. 1993

TABLE 1 continued

¹⁴ C/C ratio (pmc) (± 1 S.D.)	Material	Reference
0.1 ± 0.01	Graphite (NBS)	Donahue et al. 1990
0.1 ± 0.05	Petroleum, cracked	Gillespie & Hedges 1984
0.098 ± 0.009*	Marble	Schleicher et al. 1998
0.092 ± 0.006	Wood	Kirner et al. 1995
0.09 – 0.18* (range)	Graphite powder	Aerts-Bijma et al. 1997
0.09 – 0.13* (range)	Fossil CO ₂ gas	Aerts-Bijma et al. 1997
0.089 ± 0.017	Graphite	Arnold et al. 1987
0.081 ± 0.019	Anthracite	Beukins 1992
0.08 ± ?	Natural Graphite	Donahue et al. 1984
0.077 ± 0.005	Natural Gas	Beukins 1992
0.076 ± 0.009	Marble	Beukins 1992
0.074 ± 0.014	Graphite powder	Kirner et al. 1995
0.07 ± ?	Graphite	Kretschmer et al. 1998
0.068 ± 0.009	Graphite (fresh surface)	Schmidt et al. 1987
0.06 – 0.11 (range)	200 Ma old graphite	Nakai et al. 1984
0.060 – 0.932 (range)	Marble	McNichol et al. 1995
0.056 ± ?	Wood (selected data)	Kirner et al. 1997
0.05 ± 0.01	Carbon	Wild et al. 1998
0.05 ± ?	Carbon-12 (mass sp.)	Schmidt, et al., 1987
0.045 – 0.012 (m 0.06)	Graphite	Grootes et al. 1986
0.044 ± ?	Coal Tar	Farwell et al. 1984
0.04 ± ?*	Graphite rod	Aerts-Bijma et al. 1997
0.04 ± 0.01	Finnish graphite	Bonani et al. 1986
0.04 ± 0.02	Graphite	Van der Borg et al. 1997
0.036 ± 0.005	Graphite (air)	Schmidt et al. 1987
0.033 ± 0.013	Graphite	Kirner et al. 1995
0.03 ± 0.015	Carbon powder	Schleicher et al 1998
0.030 ± 0.007	Graphite (air redone)	Schmidt et al. 1987
0.029 ± 0.006	Graphite (argon redone)	Schmidt, et al., 1987
0.029 ± 0.010	Graphite (fresh surface)	Schmidt et al. 1987
0.02 ± ?	Carbon powder	Pearson et al. 1998
0.019 ± 0.004	Graphite (argon)	Schmidt et al. 1987
0.014 ± 0.010	CaC ₂ (technical grade)	Beukins 1993
0.01 ± ?**	Dolomite (clean)	Middleton et al. 1989
0 ± 0.0000004	Methane	Beukins 1993

*Estimated from graph

**Lowest value of multiple dates

accelerator. Remember that there is no difference between these experiments and those that have an empty sample holder, except the sample. So any difference between the experiments must be explained by something which goes through the accelerator. But after the accelerator there is a magnet which separates the beam by its charge-to-momentum ratio. So any ion which strikes the detector in the first place must have the charge-to-momentum ratio of carbon-14. Second, the amount of energy lost creating ions in a defined thickness of semiconductor material is measured, and only one narrow range of values is consistent with carbon-14 that has traveled through the accelerator. Third, the total energy, measured by ions created in a thickness of semiconductor thick enough to stop the carbon-14, is measured. This again results in a narrow range of acceptable values consistent with carbon-14.

These three tests are enough by themselves to uniquely identify carbon-14 and to distinguish it from nitrogen-14, carbon-13 with hydrogen, carbon-12 with two hydrogens or with deuterium, two lithium-7 atoms, other molecular species, or cosmic rays. However, in some experiments, most notably Bonani et al. (1986), the time of flight of each particle between the ion stripper in the middle of the tandem accelerator and the detector was also measured, and it was also consistent with carbon-14 and not with other molecular species. Thus one can be quite sure that the atoms that are being detected are indeed carbon-14.⁷

NUCLEAR SYNTHESIS OF CARBON-14 *IN SITU* IS NOT AN ADEQUATE EXPLANATION

The next explanation that might be made is that these carbon-14 atoms are created by nuclear reactions while the sample is in the ground. This is highly improbable. Zito et al. (1980) calculated that groundwater in granite could possibly have carbon with a carbon-14 concentration of 0.00266 pmc. Florkowski et al. (1988) corroborated their calculations. If one reworks the calculations using oil, one comes up with 2.7×10^{-8} pmc (Giem 1997a, p 186-187). This is well below the range capable of explaining the above experiments.

One can hypothesize that neutrons were once much more plentiful than they are now, and that is why there is so much carbon-14 in our experimental samples. But the number of neutrons required must be over a million times more than those found today, for at least 6,000 years; and every 5,730 years that we put the neutron shower back doubles

the number of neutrons required. Every time we halve the duration of the neutron shower we roughly double its required intensity. Eventually the problem becomes insurmountable. In addition, since nitrogen-14 captures neutrons 110,000 times more easily than does carbon-13, a sample with 0.000 0091% nitrogen should have twice the carbon-14 content of a sample without any nitrogen. If neutron capture is a significant source of carbon-14 in a given sample, radiocarbon dates should vary wildly with the nitrogen content of the sample. I know of no such data. Perhaps this effect should be looked for by anyone seriously proposing that significant quantities of carbon-14 were produced by nuclear synthesis *in situ*.

CONTAMINATION *IN SITU* EXPLAINS SOME, BUT PROBABLY NOT ALL, THE RESULTS

Contamination *in situ* is sometimes used to explain the persistent residual carbon-14 found in these experiments. Some experiments virtually demand this explanation as at least a contribution to the results obtained. For example, Schleicher et al. (1998) note that relatively untreated foraminifera gave 0.401 ± 0.084 pmc, whereas foraminifera treated with various methods for removal of contamination gave a smaller $^{14}\text{C}/\text{C}$ ratio, reaching 0.166 ± 0.008 pmc when using a purification procedure including 30% H_2O_2 and 15 min of ultrasonic treatment, and attachment to the carbonate system wet. This is highly unlikely ($p < 0.001$) to be due to chance. However, it appears that the best data on fossil carbon with a published standard deviation, other than Beukins (1992), Kirner (1995), and Beukins (1993), all cluster at about 0.15 pmc and are not statistically different from one another (see Figure 1). It is difficult to imagine a natural process contaminating wood, whalebone, petroleum and coal, all to roughly the same extent. It is especially difficult to imagine all parts of a coal seam being contaminated equally.

However, contamination *in situ* is a more likely consideration than is nuclear synthesis *in situ* or machine error. One could evaluate the contamination hypothesis by carefully testing different samples, such as coal from different parts of a seam, and from different depths, coke, coal tar, petroleum, and wood. If all sources come out with similar amounts of carbon-14, we can be reasonably sure that contamination *in situ* is not a good explanation for the observed amount of carbon-14. The available data suggest this to be the case, but do not quite prove it.

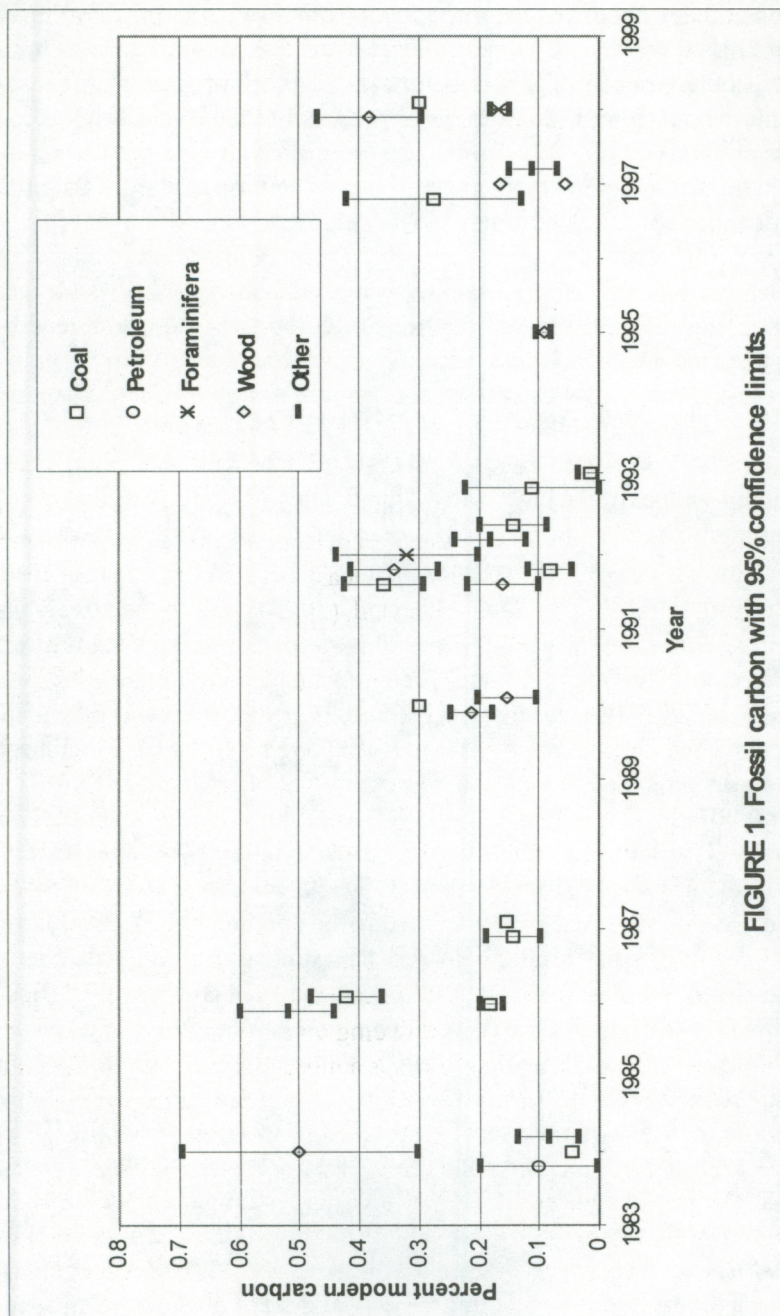


FIGURE 1. Fossil carbon with 95% confidence limits.

On the other hand, if we are consistently able to get significantly lower $^{14}\text{C}/\text{C}$ ratios with some samples of pre-Pleistocene fossil carbon than with others, this suggests that the differences between the $^{14}\text{C}/\text{C}$ ratios in the various samples may reasonably be explained by contamination *in situ*.

CONTAMINATION DURING SAMPLE PROCESSING EXPLAINS SOME, BUT PROBABLY NOT ALL, THE RESULTS

Contamination during sample processing is the most frequent explanation of carbon-14 in samples expected to be "dead" by long-age theories. There is good evidence that contamination during sample processing often occurs, and that some of the carbon-14 found in these samples may be accounted for on this basis. For example, Middleton et al. (1989) measured one dolomite sample that had 0.01 pmc when handled with extreme care, and 0.5 pmc when handled with less care. Van der Borg et al. (1997) noted graphite to have 0.04 ± 0.02 pmc when measured without reprocessing, and 0.18 pmc when tested after recycling. Arnold et al. (1987) reported a graphite having 0.089 ± 0.017 pmc without recycling, and 0.34 ± 0.11 pmc after recycling (statistically significant at $p < 0.025$). Schmidt et al. (1987) analyzed several samples of graphite that varied in $^{14}\text{C}/\text{C}$ ratio depending on the care used in preparation. Perhaps most impressively, Schmidt et al. noted a finite "age" (0.05 pmc) for carbon-12 obtained from a Faraday cup in their AMS machine, that was functioning as a mass spectrometer to separate carbon-12 from carbon-14. Contamination during sample processing cannot be ignored. Therefore, results for coal higher than about 1 pmc, which seem to me to be likely to be due to contamination, have not been reported in this paper.

However, contamination is not necessarily inevitable. Some parts of the process do not have to add contamination when done carefully. Beukins (1992) reported anthracite (0.081 ± 0.019), natural gas (0.077 ± 0.005), and marble (0.076 ± 0.009) samples that had essentially the same $^{14}\text{C}/\text{C}$ ratio. Since each of these materials is processed differently, these results show that all steps in sample preparation except the reduction step can be done in such a way as to avoid contamination.

It is possible that the iron sometimes used to reduce carbon dioxide to carbon is a source of contamination. In one experiment (Brown et al. 1983), this iron contained carbon with a 1.5 pmc $^{14}\text{C}/\text{C}$ ratio.

One of the consistent findings in these experiments is that graphite dates older (i.e., has a lower $^{14}\text{C}/\text{C}$ ratio) than fossil carbon. Marble and calcite give intermediate results, at least in the best experiments. This is true not only for the overall list but also for several experiments where graphite was directly compared with fossil carbon from various sources (e.g., Schmidt et al. 1987, Aerts-Bijma et al. 1997, Grootes et al. 1986, Vogel et al. 1987). Interestingly, the lowest $^{14}\text{C}/\text{C}$ ratio is for dolomite. It has been suggested that the form of the sample influences the amount of contamination. In general, the samples that have to be manipulated the most, and specifically those that require reduction from carbon dioxide to carbon, tend to have higher $^{14}\text{C}/\text{C}$ ratios. The dolomite noted above may not be an exception, as it was measured directly as carbon dioxide without being reduced (one of the few experiments to try this technique).

However, it should be noted that some of the graphite samples, and perhaps most of them, come from Finland, where there is Precambrian graphite. In one such case the graphite is specified to be from the bedrock of Finland (Bonani et al. 1986). An equally good hypothesis for the difference between $^{14}\text{C}/\text{C}$ ratios in graphite and coal is that Precambrian graphite was not in equilibrium with the pre-Flood biosphere and should have lower residual carbon-14 levels than fossil carbon from the Flood.

RESIDUAL ACTIVITY IS THE MOST LIKELY EXPLANATION FOR CARBON-14 IN PRE-PLEISTOCENE MATERIAL

To summarize, there are two competing theories for the higher $^{14}\text{C}/\text{C}$ ratio in fossil material compared to graphite. The first is that there is contamination from the reduction step. The second is that there is more residual carbon-14 in fossil material than there is in graphite. Differences between these theories are testable.

One way to test these competing explanations is to oxidize graphite and run it through the same reduction step as the other materials. This has been done (Van der Borg et al. 1997), and the results were 0.18 ± 0.04 pmc. This result clearly indicates contamination during the reduction process.

Another way to test these explanations would be to use a method that does not require reducing the carbon dioxide from fossil carbon, but instead measures it directly. Measuring the carbon-14 in carbon dioxide directly has been done by Middleton et al. (1989), but I have not

found any reports of experiments that compared carbon dioxide from fossil carbon with carbon dioxide from Precambrian or other non-fossil carbon.

Another way to test these explanations is to prepare graphite directly from fossil carbon without first turning the fossil carbon into carbon dioxide. This has been done in at least five experiments. Terrasi et al. (1990) measured coke directly and obtained 0.3 pmc. Beukins et al. (1992) used calcium carbide presumably produced by heating calcium oxide with coal, made acetylene, and cracked it directly to carbon. They obtained a $^{14}\text{C}/\text{C}$ ratio of 0.142 ± 0.028 pmc. Gillespie and Hedges (1984) cracked petroleum directly. They obtained a $^{14}\text{C}/\text{C}$ ratio of 0.1 ± 0.05 . And Farwell et al. (1984) cracked coal tar directly, and obtained a $^{14}\text{C}/\text{C}$ ratio of 0.44. These results are compatible with the lowest data from oxidized fossil carbon, and higher than those consistently found in graphite (0.03 pmc). Finally, there are the data of Beukins (1993), which will be discussed below.

Perhaps the best way to test these explanations is to compare Phanerozoic graphite with Precambrian graphite. I am not sure that the graphite samples with the lowest $^{14}\text{C}/\text{C}$ ratios are Precambrian, but the assumption is not an unreasonable one (Giem 1997a, p 184). There is one reported experiment that gave a Phanerozoic date for the graphite used (Nakai et al. 1984). Their results ranged from 0.06 to 0.11 pmc, compatible with the results for fossil carbon noted above, and higher than those consistently found in graphite which could be Precambrian. These data argue for residual carbon in fossil carbon (and against contamination during the reduction step).

However, none of the experiments mentioned above were done to test the differences between the various theories. Perhaps the most interesting experiment was reported by Kirner et al. (1997). Part of the background is as follows: R. E. Taylor was aware that short-age constant-decay theories predicted that there should be >0.005 pmc in fossil carbon (Giem 1997a, p 180-187). Taylor believed that he should be able to obtain $^{14}\text{C}/\text{C}$ ratios lower than those commonly published, and that could possibly match or even surpass those obtained from graphite. The results his group obtained include several measurements with an average of 0.162 pmc. The lowest value they obtained was 0.056 ± 0.004 pmc.⁸ Their conclusions were that the data were best explained as the sum of a constant amount of contamination by modern carbon regardless of

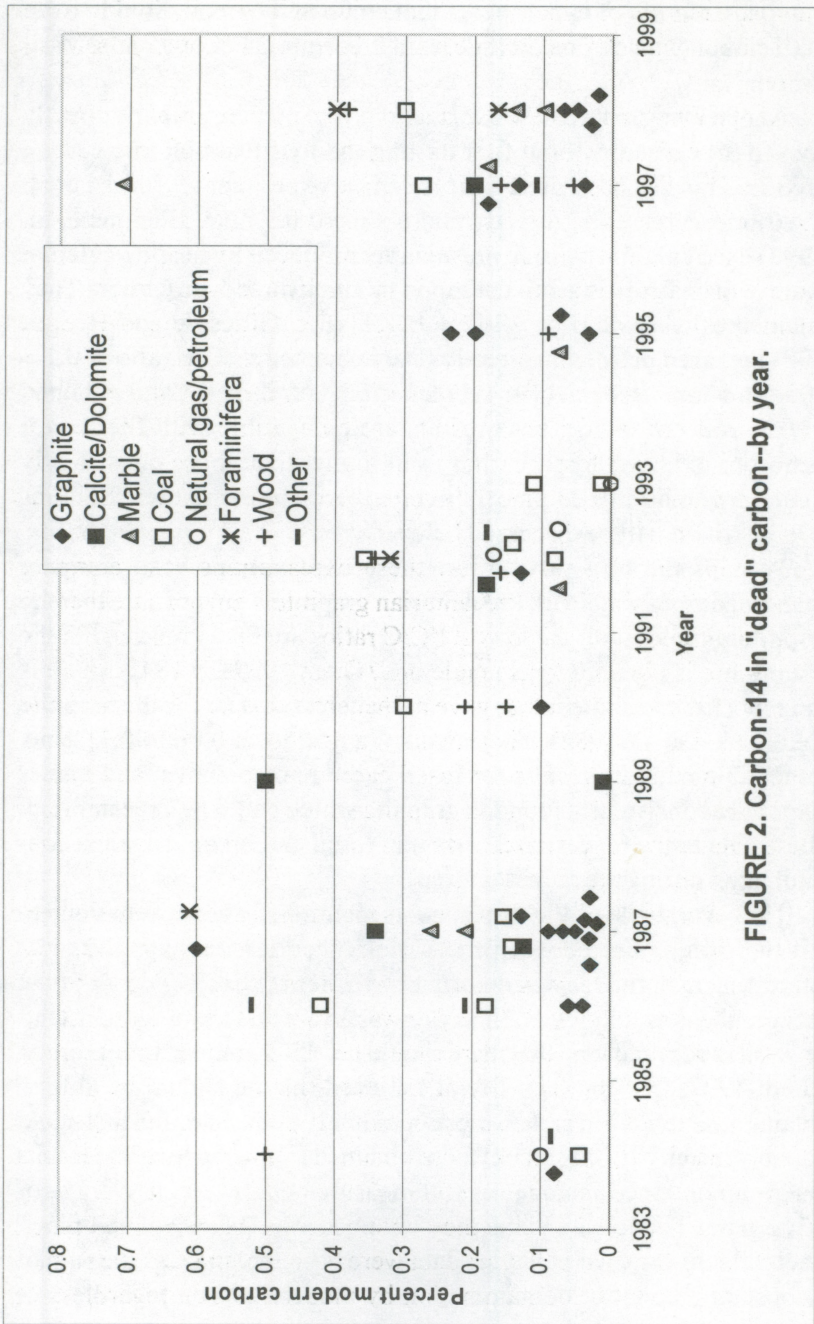


FIGURE 2. Carbon-14 in "dead" carbon--by year.

sample size, plus a constant proportion of carbon-14 equivalent to 0.12 ± 0.02 pmc. The constant proportion of carbon-14 "could arise if our wood blank was not truly ^{14}C dead either due to a finite age or the result of the presence of residual contamination not removed by chemical treatment." These data argue for the theory of residual carbon-14 in fossil carbon.

One explanation of the data was that it was due to contamination that was gradually getting less with time, as laboratory techniques improved. However, from the graph in Figure 2, it is difficult to detect a trend with time.⁹ The lowest values for graphite, and the lowest values for coal, are not the most recent determinations.

Two additional results deserve special attention. Beukins (1993) reports that technical grade calcium carbide, when hydrolyzed to acetylene and cracked, produced graphite with a $^{14}\text{C}/\text{C}$ ratio of 0.014 ± 0.010 pmc. This is in contrast to his previously reported 0.142 ± 0.028 pmc (Beukins 1990, also reported in Gurfinkel 1987). Commercial calcium carbide is usually prepared from coal and calcium oxide. If one assumes this is the case here, the 0.014 pmc value reported is possibly the lowest $^{14}\text{C}/\text{C}$ ratio for fossil carbon in the literature.

There is also a report of carbon monoxide prepared from methane purified from natural gas (again in Beukins 1993), which was isotopically enriched. The enrichment process apparently was done several times, and the most enriched fraction, in which carbon-14 was theoretically enriched 20,000-fold, had essentially the same $^{14}\text{C}/\text{C}$ ratio (uncorrected for enrichment) as the unenriched fraction. Taken at face value, these results suggest that the natural gas had a $^{14}\text{C}/\text{C}$ ratio of $0.000\ 000\ 0 \pm (4 \times 10^{-7})$, and that either this particular natural gas was not fossil material (see Planetary Sciences Unit 1982), or that short-age constant-decay models are incorrect (as noted above, most reasonable short-age constant-decay models require a $^{14}\text{C}/\text{C}$ ratio above 0.005 pmc).

According to one explanation of the data discussed above, all the carbon-14 found in material classified as pre-Pleistocene represents contamination. In that case one has to explain why careful researchers are commonly unable to obtain carbon with less contamination from modern carbon than 1 part in 1,000. One would be encouraged by the data of Beukins (1993), but would have to put it into perspective, especially considering the data of Kirner et al. (1997). Further experiments which might bolster this hypothesis include repeating the experiments of

Beukins, using coal from deep underground with minimal opportunity for contamination, and trying isotope enrichment experiments, which may be easier to keep clean.

A second explanation of the data is that material classified as pre-Pleistocene Phanerozoic may contain actual residual carbon-14, and that the level of carbon-14 may be estimated by the data given by Beukins (1993). This explanation assumes that the amount of carbon-14 in coal is reliably estimated at 0.014 pmc (95% confidence limits 0.0025 to 0.044 pmc).¹⁰ This fits with the creationist predictions noted above. It still assumes less than careful technique in most of the experiments, but not to quite the same degree as the hypothesis of complete contamination. Differentiating this hypothesis from that of complete contamination would probably require measuring very pure carbon from coal, using perhaps the method of Beukins (1993), and comparing it with carbon-12 and carbon-13 separated from any possible contamination by carbon-14 using a mass spectrometer. One would have to be meticulous in one's technique, and use the largest masses possible.

A third explanation of the above data is that the data given by Beukins (1992) are approximately correct and that higher measured levels of carbon-14 in "old" carbon represent contamination. The ¹⁴C/C ratio for carbon in coal is then in the range of 0.052 to 0.12 pmc. The upper value is within the limits of error of several of the lower measurements for coal. It is also within range of the measurements on 200 Ma old graphite by Nakai et al. (1984). It fits the estimate of contamination/residual activity of Kirner et al. (1997). The only measurements lower than this on possibly fossil material are those on coal tar by Farwell et al. (1984), and calcium carbide and methane by Beukins (1993). The result obtained by Farwell et al. does not have a reported standard deviation, and so it may not be in serious conflict with this hypothesis. The data on calcium carbide by Beukins is in conflict, but should not be determinative until it is reproduced, especially considering the wide confidence limits. The major challenge to this hypothesis is the data on methane by Beukins. If this is reproducible and theoretically sound, it would indicate that a substantial proportion of natural gas has no carbon-14. However, until similar results are obtained for coal, fossil shells, or other definitively fossil material, it cannot destroy the hypothesis that fossil material has significant amounts of carbon-14. Of the hypotheses outlined above, I find this third hypothesis to present the case for explaining the data at present.

Hypotheses which propose that there is less than a given level of carbon-14 in a given fossil material should predict that, with the proper care, we can find fossil material that measures less than that level. On the other hand, hypotheses which propose that there is a certain level of carbon-14 in a given fossil material should predict that, with the proper care, we can measure less than that level with other carbon (for example, from a mass spectrometer), and not with the fossil material in question. It will be interesting to follow the results of future experiments.

There is one other possibility that has not been discussed yet. The pre-Flood biosphere may not have been in equilibrium, or even pseudo-equilibrium. It is possible that the atmosphere was not as well mixed as at present, and that various reservoirs of carbon may have had different $^{14}\text{C}/\text{C}$ ratios. Thus the data noted by Brown (1988) and even that reported by Snelling (1997, 1998, 1999) may not be in error. Rather, we may be seeing a spectrum of activity. This hypothesis is also a shortage hypothesis. It has not been discussed, not so much because it cannot be correct, but because it makes no specific testable predictions. It does predict that somewhere there should be residual carbon-14 in antediluvian samples, but it does not predict that any given specimen should have a measurable percentage of carbon-14.

RESIDUAL ACTIVITY WOULD ELIMINATE AN AGE GREATER THAN 100,000 YEARS FOR LIFE ON EARTH

The existence of truly residual carbon-14 in material that has been assigned an age greater than 300,000 years would invalidate long-age theories. As noted above, any specimen of greater age than 300,000 years should have less than 1 atom of carbon-14 per gram of carbon. If the entire earth were made of nothing but carbon-14, all but one atom would decay to nitrogen-14 in 1 million years, and that atom would have a greater than 99% chance of also decaying. In 2 million years the weight of the entire known universe in carbon-14 could decay to nitrogen. Thus if there is residual activity in material considered to be 350 million years old, or 2 million years old, or even 300,000 years old, the material in question simply is not that old. In view of our previous discussion, it is probably not even 100,000 years old.

It is interesting to follow the implications of the data further. Since it is believable that most fossil carbon has roughly the same $^{14}\text{C}/\text{C}$ ratio, it is reasonable to conclude that all this carbon was in the biosphere at

approximately the same time. In that case, since most, if not all, fossil carbon was deposited by water, the data suggest a flood of massive proportions, and that the biblical account has to be taken seriously. If the difference between fossil carbon and Precambrian carbon is approximately 0.05 pmc, and we assume that 0.05 pmc is the true level of residual carbon-14 in pre-Flood fossil carbon, then the first simplistic approximation to the time of burial of fossil carbon is 19,000 years ago. A reasonable upper limit for the time of burial is 25,000 years ago, and with favorable assumptions regarding the pre-burial $^{14}\text{C}/\text{C}$ ratio, a time of burial as recent as 4,300 years ago (the traditional Masoretic date for the Flood) is not unreasonable from these considerations alone.

FURTHER STUDY CAN PROVIDE MORE EVIDENCE FOR THE AGE OF LIFE ON EARTH

The data we have at present, although they are most easily interpreted as against a long age for life on Earth, cannot prove a short age. Even more data cannot prove either a short or a long age. First, there are legitimate questions that can be raised about any data, present or future. Proof is elusive in science. It will always remain possible that the available data may be interpreted another way, or is inaccurate. For someone who doubts a short age for life on Earth on other empirical grounds, those doubts may outweigh the positive evidence noted above, or even outweigh further experimental evidences, although at some point the accumulated evidence regarding this phenomenon should outweigh other evidence if it is sufficiently corroborated.

Second (and less legitimately), if a short (or a long) age for life on Earth is philosophically ruled out, no amount of evidence matters. The entire exercise of science then degenerates into an attempt to find evidence to support one's philosophical position, and science ceases to be a search for truth. Then the above data are not allowed to teach anything, and are simply utilized for the sake of argument, or else discounted in an attempt to prevent their use by someone with an opposing view.

For anyone who is seriously considering both a long age and a short age of life on Earth, the above data support the latter and argue against the former. Additional experiments may further support a short age, or change that picture. In either case further experiments can become important, as they help one make an important choice in one's worldview.

ENDNOTES

1. Readers unfamiliar with carbon-14 dating may find it helpful to consult my previous article on the subject (Giem 1997b), or to consult a general introduction, such as Geyh and Schleicher 1990, p 162-180.
2. It is theoretically possible to propose that life has been here for 1-4 billion years and that radioactive decay constants have not remained constant during that time. However, this position would require that one accept a timescale based on mechanistic and uniformitarian assumptions while denying those assumptions. I do not know of anyone who seriously proposes such a theory.
3. The mathematics are as follows: If we call the original $^{14}\text{C}/\text{C}$ ratio R_0 , and use a maximum R_0 of 10 (compared to the "modern" [1850] $^{14}\text{C}/\text{C}$ ratio), and if we call the half-life of carbon-14 h , and use the most accurate h (5,730 years) for our calculations, and if we express the results R in pmc, then the formula for a given sample is

$$\begin{aligned} R &= 100\% \times 2^{(-t/h)} \times R_0 \\ &= 1000\% \times 2^{(-t/5730 \text{ years})}. \end{aligned}$$

For 100,000 years, $R = 5.577 \times 10^{-3}$ pmc. For 200,000 years, $R = 3.111 \times 10^{-8}$ pmc, and for 300,000 years, $R = 1.735 \times 10^{-13}$ pmc. Since in a gram of ordinary carbon at "present" there are 5×10^{12} atoms of carbon-14, in a 300,000-year-old specimen there should be 0.009 atoms of carbon-14 per gram of carbon.

4. Coal is obviously largely fossil material. Natural gas may or may not be (see Planetary Sciences Unit 1982). Evidence for petroleum being of fossil origin would include optically active compounds and compounds usually derived from organisms.
5. Equilibrium with the biosphere means that there is enough exchange of carbon between the biosphere and the given material that the $^{14}\text{C}/\text{C}$ ratio in the given material is the same as that in the biosphere.
6. Some predictions of machine background include >100,000 radiocarbon years (<0.0004 pmc) (Muller 1977), less than 1 count per run (>50,000-60,000 years) (Nelson et al. 1977), less than 1 count per day (Doucas et al. 1978), and >70,000 radiocarbon years (<0.016 pmc) (Bennett et al. 1977).
7. In some experiments, only the total energy of the particles (and their position) is measured. In this case there is some overlap between the tail of the carbon-13 peak and the carbon-14 peak. In these experiments, there is more uncertainty about the background.
8. The values were published in Kirner et al. (1997). The standard deviation of the smaller value is from Taylor (personal communication 2000). The standard deviation (or more precisely standard error) of the larger value varies considerably depending on whether it is calculated experimentally or from theoretical standard deviations of the measurements. I do not have enough measurements at present to give a precise value, but estimates would range from 0.001 to 0.02 pmc.
9. The data from before 1979 are summarized in Giem (1997a, p 184). They are not plotted as they are all on graphite or dolomite.
10. If the distribution is a Poisson distribution, the 95% confidence limits are 0.0025 to 0.044 pmc. However, if the uncertainty is largely due to overlap of carbon-14 counts with the tail of carbon-13 and/or carbon-12 counts, the 95% confidence limits should be roughly 0.0 to 0.034. This is possible. Some laboratories only test one of the properties of carbon-14 to distinguish it from carbon-13, in which case there can be some overlap between the two.

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ANNOTATIONS FROM THE LITERATURE

DEVELOPMENT: ECHINODERMS SIMILAR TO BILATERIANS

Martinez P, Rast JP, Arenas-Mena C, Davidson EH. 1999. Organization of an echinoderm *Hox* gene cluster. Proceedings of the National Academy of Sciences (USA) 96:1469-1474.

Summary. Echinoderms have 5-fold symmetry, whereas most other multicellular animals have bilateral symmetry. *Hox* genes are thought to be major determinants of body plan through their influence on development. Thus, one might expect to find some notable differences in the *hox* gene arrangement of echinoderms compared with bilaterians. This hypothesis was tested by comparing the *hox* complex of the sea urchin *Strongylocentrotus purpuratus* with the *hox* complex in chordates. Although there were some differences, the two *hox* complexes were remarkably similar, despite their radical differences in body plans.

Comment. This result adds to evidence that development is far more complex than indicated by comparisons of *Hox* gene complexes. *Hox* genes may function as gene regulatory elements that turn on and off other genes, with developmental differences being due to differences in the genes being regulated.

DEVELOPMENT: HOX FOR ADULTS?

Arenas-Mena C, Martinez P, Cameron RA, Davidson EH. 1998. Expression of the *hox* gene complex in the indirect development of a sea urchin. Proceedings of the National Academy of Sciences (USA) 95:13062-13067.

Summary. Sea urchins have a *hox* gene complex of 10 genes that play an important role in development. Sea urchin development includes two major phases — first a bilateral larval stage, then a 5-fold symmetric adult. Only two of the ten sea urchin *hox* genes are expressed throughout development, while all of them are expressed during formation of the adult body plan. There was no obvious relationship between sequence of genes in the cluster and location of gene activity during development. It appears that larval development may

not depend on the *hox* genes, while development of the adult does. This suggests that the *Hox* cluster may not be required for development of all bilaterians, although it may be necessary for development of the adult body plan in complex metazoans.

Comment. In conventional evolutionary theory, organisms are more similar in their earlier developmental stages, but diverge in later stages. Similarities in *hox* gene sequences are interpreted as indicating common ancestry. However, if the earlier stages of development are the most similar, and the *hox* genes affect primarily the adult stages, the *hox* genes do not really seem to be good evidence for common ancestry.

DINOSAURS: A BIRD IN THE HANDS?

Wagner GP, Gauthier JA. 1999. 1,2,3 = 2,3,4: a solution to the problem of the homology of the digits in the avian hand. *Proceedings of the National Academy of Sciences (USA)* 96:5111-5116.

Summary. Differences in "fingers" of dinosaurs and birds have been used to argue against the dinosaurian ancestry of birds. Theropod digits are identified as numbers 1, 2, and 3, whereas embryological evidence indicates that birds have digits 2, 3, and 4. This paper argues that the digits may not be strictly homologous in the classical sense, but that their development is affected by the presence of nearby morphological structures. Alligators in which mitosis is inhibited during development produce a single finger with mixtures of first and second finger traits. Kiwis have only two fingers (2 and 3), but when finger 2 is absent or reduced, finger 3 may assume some of its traits. Thus, there may have been a shift in development so that avian digits 2,3 and 4 have assumed the morphological traits of theropod digits 1,2 and 3.

Feduccia A. 1999. 1,2,3 = 2,3,4: accommodating the cladogram. *Proceedings of the National Academy of Sciences* 96:4740-4742.

Summary. The hypothesis that birds descended from dinosaurs faces insuperable problems. There is no evidence to support the proposal that avian and dinosaurian fingers should be considered homologous because of a frameshift in development. No theropod fossils indicate a frameshift occurring. The hand of *Archaeopteryx* is not as similar to theropod hands as some drawings seem to indicate.

Avian forelimb and hindlimb development show the same developmental pattern, and it seems implausible that this could be due to a frameshift in the forelimb but not in the hindlimb.

The dinosaurian ancestry of birds is linked to the notion that avian flight began from the ground up, in "hot-blooded" dinosaurs. The ground-up theory of the origin of flight is considered a near biophysical impossibility. *Archaeopteryx* appears in the fossil record 30 to 80 million years before its putative dinosaurian ancestors, which become more and more superficially birdlike toward the end of the Cretaceous. The hypothesis that dinosaurs were warmblooded has been refuted. *Archaeopteryx* has been shown to be distinctly birdlike, with wings similar to woodland birds, asymmetric flight feathers, a scapula/coracoid arrangement for flight, and a reversed hallux found only in perching birds.

Claims of feathered dinosaurs have been refuted. Preserved theropod skin is clearly reptilian, with no trace of feathers. *Sinosauropteryx* does not have feathers, but a row of collagen fibers that supported a frill along the back. *Caudipteryx* has features indicating it is a secondarily flightless bird, including a propterygostyle, an avian occipit, and a probable herbivorous diet. *Protoarchaeopteryx* teeth appear to lack theropod-like serrations. *Confuciusornis* is clearly an arboreal bird, not a terrestrial predator.

Further problems with the dinosaur-bird hypothesis include the conversion of a piston-like breathing system to the avian flow-through lung, change in body balance, and re-elongation of previously shortened forelimbs. The 1,2,3 = 2,3,4 hypothesis is an example of allowing the cladogram to determine the data rather than the reverse.

Comment. Although there are some similarities among dinosaurs and birds, there are some severe problems with the hypothesis of an evolutionary link between them. Separate ancestries for the two groups is still a reasonable position to take.

DINOSAURS: NON-AVIAN LUNGS

Ruben JA, Dal Sasso C, Geist NR, Hillenius WJ, Jones TD, Signore M. 1999. Pulmonary function and metabolic physiology of theropod dinosaurs. *Science* 283:514-516.

Summary. Birds are widely claimed to be descended from theropod dinosaurs. However, theropod osteology resembles that of croco-

diles more than of birds, and suggests that theropods may have lungs resembling those of crocodiles instead of the unique system found in birds. Well-preserved remains of certain dinosaurs appear to indicate a non-avian respiratory system. For example, the theropod *Sinosaur-opteryx* (Compsognathidae) appears to have a vertical separation between the thoracic and abdominal cavities, as in crocodilians. *Scipionyx samniticus* is a new maniraptoran dinosaur from Italy, with excellent preservation. Portions of the internal organs are preserved, and indicate the posterior colon is located in the crocodilian position rather than the avian position. Remnants of what appear to be the diaphragm are also preserved, along with evidence the thoracic and abdominal cavities were separated by the liver. All these features point to a theropod metabolism more similar to crocodiles than to birds.

Comment. Dinosaurs and birds share several similarities which have been used to argue for their evolutionary linkage. However, significant differences are also known, which may be used to argue against their evolutionary linkage. Although the supposed evolutionary relationship of dinosaurs and birds is strongly promoted by some, many find the scientific obstacles too great to accept this hypothesis.

EVOLUTION: PARALLEL MORPHOLOGICAL CHANGES IN DARWIN'S FINCHES?

Freeland JR, Boag PT. 1999. The mitochondrial and nuclear genetic homogeneity of the phenotypically diverse Darwin's ground finches. *Evolution* 53:1553-1563.

Summary. Darwin's finches are among the most famous birds in the world, but surprisingly little is known about their evolutionary history. The group includes four genera, including six species of ground finches in the genus *Geospiza*. Mitochondrial DNA sequences were compared for several species.

Groupings of species of *Geospiza* based on DNA sequence similarities were different from those based on morphology. Birds from a given "species" were in some cases more similar to birds from another "species" on the same or a different island. None of the studied "species" was monophyletic. For example, one grouping consisted of some *G. scandens* and some *G. fortis* from Santa Cruz Island and *G. conirostris* and *G. magnirostris* from Genovesa Island. Other *G. scandens* from Santa Cruz were closest to *G. difficilis*

from Genovesa, while other *G. fortis* from Santa Rosa Island were closest to *G. scandens* from Marchena and *G. fuliginosa* from Santa Cruz. The lack of genetic separation of morphological species might reflect ancestral polymorphism, but the strongest factor is likely to be hybridization, which is known to occur. Failure to identify genetic markers for the *Geospiza* morphological species calls into question the validity of considering them as different biological species.

Comment. This example illustrates the degree of variability present in these birds, and the potential for splitting one species into several. The possibility of parallel evolution in these birds, producing similar morphologies from different ancestral stocks, would make an interesting study.

EVOLUTION: DARWIN'S FINCHES — HOW MANY SPECIES?

Sato A, O'hUigin C, Figueroa F, Grant PR, Grant BR, Tichy H, Klein J. 1999. Phylogeny of Darwin's finches as revealed by mtDNA sequences. *Proceedings of the National Academy of Sciences (USA)* 96:5101-5106.

Summary. Mitochondrial DNA sequences were compared for the 14 recognized species of Darwin's finches. The group includes six species of ground finches, six species of tree finches, and two species of warbler finches. All are confined to the Galapagos Islands except for one species of warbler finch, which lives only on Cocos Island.

Molecular data provided different results from the morphological data. The ground finches grouped together, but no separate species could be distinguished. Four of the five tree finches (one species was not available for study) grouped together with the Cocos island warbler finch. The four tree finch "species" were not reliably distinguished by molecular data. The other tree finch, *Platypiza crassirostris*, did not group with any other species. The Galapagos warbler finch also was separate. Failure to distinguish morphologically based species of ground and tree finches was explained as due to retention of ancestral polymorphisms and hybridization.

Comment. Populations that hybridize sufficiently so that they cannot be reliably distinguished on molecular grounds could legitimately be considered the same species. The Galapagos finches studied

could be considered to be four species rather than 13. Constructing a satisfactory definition of species is difficult in situations like this where morphological patterns are inconsistent with molecular patterns.

EVOLUTION AND THE PUBLIC: SCIENTISTS RETAIN THEIR FAITH

Larson EJ, Witham L. 1999. Scientists and religion in America. *Scientific American* (September):88-93.

Summary. James H. Leuba conducted a survey of religious faith among scientists in 1914 and again in 1933. The survey asked whether the scientist believed in a God who answers prayer and an afterlife. Leuba noted that there was less belief in God among the scientific elite (as noted in *American Men of Science*), and predicted that belief among all scientists would decline. This survey was repeated in 1996 and 1998, and the results reported here. Leuba's prediction was refuted. The number of believing scientists remains at the same level as in 1914 — about 40%. The number of disbelieving "elite" scientists has increased from 80% to 90%. (The more recent survey defined "elite" scientists as members of the National Academy of Sciences.) According to Ernst Mayr, scientists have difficulty believing in the supernatural, and in a god who would tolerate all the evil in the world. Some scientists have found a "religious" experience in evolutionary belief. The authors attribute the current conflict between science and religion as due to the desire of religious people to use the authority of science to support their views.

Comment. It is interesting that the proportion of believing scientists has remained the same, despite what appears to be an increasing secularization of culture.

GENETICS: NO END TO VARIABILITY

Papadopoulos D, Schneider D, Meier-Eiss J, Arber W, Lenski RE, Blot M. 1999. Genomic evolution during a 10,000 generation experiment with bacteria. *Proceedings of the National Academy of Sciences (USA)* 96:3807-3812.

Summary. Twelve populations of the bacterium *E. coli* were established from a single common ancestor. For two populations, samples were chosen at intervals and analyzed for mutations using restriction enzymes. The other 10 populations were not analyzed

until generation 10,000. Numerous mutant strains were detected. Some strains increased in number, then disappeared as new strains appeared. The phylogeny has the shape of a single trunk, with all branches attenuated. Most detected mutations were probably due to transpositions and chromosomal rearrangements rather than to point mutations. At the end of 10,000 generations, nearly every sample had a unique genotype. These results show that the bacterial genome undergoes significant changes over relatively short time spans.

Comment. Many creationists believe that biodiversity has increased significantly in a relatively short time, which suggests that genomic changes may occur rapidly. This experiment supports that idea, although it is uncertain whether conclusions drawn from bacterial genomes can be applied to genomes of multicellular animals.

GENETICS: MAINTAINING GENETIC DIVERSITY

Finkel SE, Kolter R. 1999. Evolution of microbial diversity during prolonged starvation. *Proceedings of the National Academy of Sciences (USA)* 96:4023-4027.

Summary. Cultures of *Escherichia coli* were incubated for more than a year without adding nutrients or removing bacteria, leading to starvation conditions. Comparison of bacterial samples showed that different mutants arose in different cultures, despite identical culture conditions. Rapid changes in DNA sequence were detected even after several months of incubation. As no single mutant strain took over a culture completely, genetic diversity was always present.

Comment. Apparently, genetic variability is not lost during starvation conditions. Other experiments indicate that stress conditions may stimulate mechanisms that produce genetic variation. Maintenance of high levels of genetic variability may make it possible for species to change rapidly.

GENETICS: IS HUMAN EXTINCTION IMMINENT?

Eyre-Walker A, Keightley PD. 1999. High genomic deleterious mutation rates in hominids. *Nature* 397:344-347. Commentary: Crow JF. 1999. The odds of losing at genetic roulette. *Nature* 397:293-294.

Summary. Harmful mutations may accumulate in a population unless they are eliminated by natural selection. The rate at which

harmful mutations occur and are eliminated can be estimated by comparing DNA sequences for necessary genes such as proteins, with non-useful sequences such as introns and pseudogenes. Comparisons are made between similar sequences in humans and chimpanzees, assuming a common ancestry some six million years ago. Since natural selection does not eliminate mutations in non-useful sequences, mutants accumulate at a rate equal to the rate of mutation (neutral theory).

This report is the first estimate of the rate of harmful mutations in humans. The resulting calculation of 1.6 harmful mutations per person per generation is based on conservative estimates of 60,000 human genes and a generation time of 25 years. It may be more realistic to estimate that humans have 80,000 genes and a generation time of 30 years. These estimates change the calculation to three harmful mutations per person per generation.

If some mutations are beneficial, the harmful mutation rate would be calculated to be higher still. These results indicate that, for every person who survives to reproduce, three persons must die due to genetic inferiority. Why are we not extinct? A more immediate concern is that these calculations suggest that human health may be in decline. Reduction in effects of natural selection through improvements in health care could accelerate the decline.

Comment. Creationists operate under different assumptions than those on which this study is based, so we may question some of the conclusions. For example, mutation rates could be measured directly from human populations, such as by comparing sequences in family members from different generations, rather than calibrating rates against the geological time scale and assumed common ancestry. In addition, recent studies indicate the human genome may have no more than 40,000 genes.

However, the overall point seems plausible, that harmful mutations are probably accumulating in human populations, and that improvements in health care will probably increase the rate of accumulation. The reason humans have not yet become extinct may be because harmful mutations have not been accumulating for six million years, but for a much shorter period of time.

HUMAN ORIGINS

Clark GA. 1999. Highly visible, curiously intangible. *Science* 283:2029-2032.

Summary. After more than a century of research, the origins of modern humans remains controversial. Though more data would be helpful, it would not bring consensus. Many issues are due to differences in biases and assumptions on the part of those studying the question. The study of European archaeological artifacts illustrates the problem. Variations in details of stone tools have often been interpreted as evidence of different people groups, but this results in implications of social groups with unreasonably large geographic extent and persistence in time. These variations have been shown to be explainable on the basis of the size and shape of the starting piece of stone. A greater recognition of the biases in interpretation would lead to doubts about some of the widely accepted generalizations of European prehistory.

Comment. The critical role of preconceived opinions in interpretation of data is seldom recognized by scientists as explicitly as here. Non-experts tend to assume they have little choice but to trust the conclusions of the experts, but, in the historical sciences especially, this entails the risk of being led astray by the power and biases of the prevailing paradigm.

HUMAN FOSSILS: NEANDERTAL MAN . . . OR NOT?

Krings M, Geisert H, Schmitz RW, Krainitzki H, Paabo S. 1999. DNA sequence of the mitochondrial hypervariable region II from the Neandertal type specimen. *Proceedings of the National Academy of Sciences (USA)* 96:5581-5585.

Summary. A previously published comparison of Neandertal and modern human mitochondrial DNA was based on a sequence of only 333 base pairs. This paper reports the comparison of an additional 340 base pairs. The number of differences between modern humans and the Neandertal sequence averages about 35 positions, with a range from 29 to 43. Modern humans differ among themselves at an average of about 11 positions, ranging up to 35. Humans differ from chimps at about 93 positions. Chimp subspecies differ at about 17 to

42 positions. Europeans were not more similar than non-Europeans to the Neandertal sequence. Based on molecular clock assumptions, the estimated time of divergence of Neandertals and modern humans is about 465,000 years. Neandertals are probably not ancestors of modern humans.

Comment. Neandertals have been proposed to be ancestral to modern Europeans. Although this study suggests otherwise, a few caveats are in order. Molecular clock estimates of rates of DNA sequence divergence are not determined experimentally, but are calibrated from estimated dates of common ancestry based on the geologic time scale. Further, it is conceivable that separately derived lineages may resemble each other more than any of them resemble their ancestor (see Schluter and Nagel 1995. *American Naturalist* 146: 292-301). Surely we have not heard the end of the Neandertal story.

MOLECULAR EVOLUTION: NEW GENE FROM OLD

Nurminsky DI, Nurminskaya MV, De Agular D, Hartl DL. 1999. Selective sweep of a newly evolved sperm-specific gene in *Drosophila*. *Nature* 396:572-576.

Summary. The fruit fly, *Drosophila melanogaster*, belongs to a group of very similar flies, but it has a unique DNA sequence located between the genes for the cell-adhesion protein annexin and the cytoplasmic dynein intermediate chain protein. In the other species, these two genes are adjacent, but in *D. melanogaster* they are separated by ten copies of a hybrid gene. The hybrid gene consists of a portion of the annexin gene combined with a portion of the dynein gene. The hybrid gene has a function — it produces a protein used in dynein in the sperm axoneme. A portion of the hybrid gene acts as a promoter, permitting regulation of the gene's activity. It is not known whether the new gene is essential, or how it functions.

The appearance of the new gene can be explained by a series of duplications and deletions. Some intronic sequences were included in the functional portion of the hybrid gene. This explanation contrasts with widely held views of how genes evolve. First, the promoter region did not "evolve," it appeared fortuitously in a single step. Second, regulatory and coding sequences were not conserved, but a new regulatory sequence formed from a previous coding

sequence, while a new coding region formed from a previous intronic sequence. Third, similarities among the promoter sequences of the genes involved are not due to common ancestry, but are of independent origin.

Comment. Assuming this interpretation is correct, this is a remarkable discovery. Evidence that a complex series of mutations may be preserved and produce new functional sequences may help creationists explain how species could change rapidly in a much shorter time span than commonly thought. Although it is stretching the point to call the hybrid gene a new gene, the production of newly functional sequences through apparently random mutations does seem to fly in the face of some probability arguments used by creationists to reject evolutionary claims. The bottom line may be that the genome contains many surprises for everyone.

ORIGIN OF LIFE: A NEW EXPLANATION FOR CHIRALITY?

Service RF. 1999. Does life's handedness come from within? *Science* 286:1282-1283.

Summary. Amino acids and sugars are produced chemically in mixtures of equal numbers of left-handed and right-handed mirror-image forms, but life depends on only left-handed amino acids and right-handed sugars. Science has been unable to explain how the two forms could be separated in the origin of life. New studies suggest the weak nuclear force might play a role in selecting one "handed" form over the other. Electrons produced during radioactive decay always have a left-handed spin. The researchers aimed a stream of left-spinning electrons at a solution of sodium chlorate, which can form either left- or right-handed crystals. The left-handed electrons produced an excess of right-handed sodium chlorate crystals. When the solution was bombarded with right-spinning positrons, an excess of left-handed chlorate crystals was produced. It is not known whether these results have any bearing on the handedness of biomolecules.

Comment. It is too early to tell how this theory will fare, but it is not obvious that crystal behavior is a good analog for formation of biological molecules.

PALEOBIOGEOGRAPHY: MADAGASCAR AND SOUTH AMERICA?

Krause DW, Rogers RR, Forster CA, Hartman JH, Buckley GA, Sampson SD. 1999. The Late Cretaceous vertebrate fauna of Madagascar: implications for Gondwana paleobiogeography. *GSA [Geological Society of America] Today* 9(8):1-7.

Summary. Present plate tectonics models show Madagascar separating from Africa during the Lower Cretaceous, and remaining isolated to the present. This isolation is difficult to reconcile with the widespread distributions of several fossil vertebrate taxa found in the uppermost Cretaceous Maevarano Formation of northwestern Madagascar. The fossil taxa include titanosaurid dinosaurs, sudamericid mammals, and possibly peirosaurid crocodiles. Each of these groups is known also from South America. This suggests Madagascar might not have been isolated during the Cretaceous. An alternative plate reconstruction shows Madagascar linked to Antarctica through the Kerguelen Plateau throughout the Lower Cretaceous. This interpretation is more consistent with the widespread distributions of Upper Cretaceous vertebrates. Curiously, none of the fossil vertebrates seems linked to any of the living Madagascan fauna.

Comment. Conflicts between plate tectonics reconstructions and fossil distributions raise serious doubts about the accuracy of plate-tectonics models. Perhaps the models can be adjusted to provide satisfactory explanations, but the history of biogeography is replete with ad hoc land bridges, disappearing continents, and unsubstantiated plate movements. Perhaps it would be useful to consider whether catastrophic models might help explain fossil distribution patterns.

PALEONTOLOGY: COMPLETENESS OF THE FOSSIL RECORD

Foote M, Sepkoski JJ. 1999. Absolute measures of the completeness of the fossil record. *Nature* 398:415-417.

Summary. Completeness of the fossil record can be estimated in different ways, such as stratigraphic completeness for a taxon, or overall taxonomic completeness. These two approaches are compared here. The probability of genus preservation per stratigraphic interval (i.e., stratigraphic completeness) is compared with the proportion of living families represented in the fossil record (i.e., taxonomic completeness). Results show that the two measures are highly

correlated, which suggests that one might be useful in estimating the other. Correlation occurred despite the fact that the stratigraphic completeness estimates are based largely on Paleozoic and Mesozoic fossils, while the Cenozoic record is quite important in estimates of taxonomic completeness. Cephalopods were an exception, in that they had a relatively complete genus-level stratigraphic record, but a poor fossil record of living families. Chondrichthyes showed the opposite tendencies, a relatively complete record for living families, but a poor record measured by stratigraphic completeness. Trilobites, graptolites and conodonts have relatively complete fossil records, contributing to their utility as stratigraphic markers.

Comment. The completeness of the fossil record is a contentious issue. If the record is highly complete, one would expect to find evolutionary links for most transitions. If the record is highly incomplete, one would expect not to be able to use fossils to correlate strata. This paper suggests that the fossil record is rather complete for certain important groups. Study of extent and rates of morphological change among such groups should be instructive in evaluating proposed evolutionary sequences.

PHYLOGENY: DISCORDANCE IN MICROBE PHYLOGENY

Lake JA, Jain R, Rivera MC. 1999. Mix and match in the tree of life. *Science* 283:2027-2028.

Summary. The basic evolutionary tree of life has been constructed from rRNA sequence comparisons. As evolutionary trees have been constructed from other gene sequences, discordance has become apparent. With whole-genome sequence comparisons now possible, it is evident that genes do not form the nested sets that would be predicted. The discordance may be explained by lateral gene transfer, where any one microorganism may contain genes from many different species. Operational genes (e.g., metabolic enzymes) seem especially subject to lateral transfer, whereas informational genes (e.g., genes in transcription, translation) do not. Genes may have been transferred from one species to another through the activity of lysogenic coliphage viruses, which are known to insert preferentially in genes for transfer RNA. Further genome sequencing is likely to reveal additional discordancies in the proposed evolutionary trees.

Comment. Lateral transfer appears to be an important cause of discordance in gene phylogenies. However, the results seem consistent also with polyphyly.

PHYLOGENY: MOLECULES VS MORPHOLOGY IN WHALES

Gatesy J, Milinkovitch M, Waddell V, Stanhope M. 2000. Stability of cladistic relationships between Cetacea and higher-level artiodactyl taxa. *Systematic Biology* 48:16-20.

Summary. Artiodactyls include the even-toed hoofed mammals such as antelopes, deer, camels, pigs and hippos. Morphological evidence indicates the monophyly of this group, but molecular evidence indicates that whales should be included. Seventeen phylogenies were compared, 16 of which are based on molecular data, with one based on skeletal and dental data. As expected, the skeletal phylogeny excluded whales from the artiodactyls. All 16 of the molecular phylogenies included the whales among the artiodactyls. The artiodactyl groups most closely linked with whales were the Hippopotamidae (six phylogenies) and the ruminants (4 phylogenies). The other six phylogenies gave more ambiguous results. When all data were considered together in a single analysis, whales grouped with hippos. Stable groups include Cetacea + Hippopotamidae, Cetacea + Hippopotamidae + Ruminantia, and Cetacea + Hippopotamidae + Ruminantia + Suina.

Comment. Conflict between molecular and morphological phylogenies is a common observation, and whales provide a good example. Molecular biologists may have the ascendancy for the moment, but one suspects the paleontologists may have the last word. The specializations of modern whales suggest to creationists that both types of phylogenies might be wrong, and that whales may not share a common ancestry with any other group.

O'Leary MA, Geisler JH. 1999. The position of Cetacea within mammalia: phylogenetic analysis of morphological data from extinct and extant taxa. *Systematic Biology* 48:455-490.

Summary. Analysis of morphological data permits inclusion of fossils in phylogenetic hypotheses. Phylogenetic trees that include fossils often have different topologies from trees based solely on extant taxa. This analysis is based on 123 morphological characters

from 10 extant and 30 extinct taxa. When fossils are included, Artiodactyla is monophyletic, and the closest group to Cetacea. When fossils are excluded, Artiodactyla is paraphyletic, with Cetacea nested within it as the sister taxon to either Ruminantia or Hippopotamidae.

Comment. If, as these authors suggest, whales are not nested within artiodactyls, the molecular similarities of whales and artiodactyls must be due to some factor other than heredity. Perhaps lateral transfer, which seems common in bacteria, occurs also in multicellular organisms. If so, similar molecular sequences could be the result of either common ancestry or common "infection."

LITERATURE REVIEWS

Readers are invited to submit reviews of current books or journal articles relating to origins. Please submit contributions to: ORIGINS, Geoscience Research Institute, Loma Linda University, Loma Linda, California 92350. The Institute does not distribute the publications reviewed; please contact the publisher directly.

INHERIT THE WIND — REVISITED

Reviewed by L. James Gibson
Geoscience Research Institute

SUMMER FOR THE GODS. Edward J. Larson. 1997, 1998. Cambridge, MA: Harvard University Press. 318 + x p. Paper, \$13.75.

We all know the story of the Scopes trial in Dayton, Tennessee in 1925: Biology teacher John Scopes violated the law by teaching evolution in his class. The fundamentalist crusader William Jennings Bryan joined the local clergy in a witchhunt to put an end to Darwin's influence. Clarence Darrow came to defend Scopes from the bigotry of the local populace. Darrow made mincemeat of Bryan, thus saving poor Scopes from those who wanted to see him put in jail for his beliefs. Wrong!

What actually happened in the summer of 1925 in Dayton, Tennessee was far different from the impression millions of Americans have received from the film parody, *Inherit the Wind*. In his Pulitzer Prize winning book, Edward Larson reviews the actual history of the Scopes trial and finds a dramatically different story from that presented in the movie.

The book consists of three sections, entitled "Before...", "During...", and "After...". The first section describes the interaction of Christianity with evolutionary theory, the rise of Fundamentalism, and the origins of the American Civil Liberties Union.

In reality, the Scopes trial was provoked by the American Civil Liberties Union, which had formed only a few years earlier, and had not yet won a case. An ACLU secretary in New York, Lucille Milner, noticed a dispatch in a Tennessee newspaper announcing that the state of Tennessee had passed a law prohibiting the teaching of evolution. She

relayed the notice to her boss, Roger Baldwin, who was looking for an opportunity to expand the ACLU's influence. The ACLU posted a notice in the *Chattanooga Times*, advertising to find a teacher willing to test the law in court.

The second section describes how the trial was initiated and conducted. Local boosters in Dayton arranged the trial, thinking it would help bring publicity to Dayton. George Rappleyea, a chemical engineer who managed the coal and iron mines in the area, read the ACLU advertisement, and brought it to the attention of Fred Robinson, the school board chairman. They agreed that it might be good for local business to stage a trial in Dayton. The two local city attorneys, Herbert Hicks and Sue Hicks (named for his mother who died at his birth) agreed to help with the prosecution if they could find a local teacher who had taught evolution after the law was enacted. Robinson called in John Scopes and explained the plan to him, and Scopes agreed to be the defendant, although he wasn't the regular biology teacher, and couldn't remember whether or not he actually taught evolution. Hicks and Scopes were close friends, and agreed to play their respective roles on opposite sides of the issue, never dreaming what the outcome would be.

The press immediately got hold of the story, and broadcast it around the country. It was clear from the description that this was not being handled the way court cases are typically handled. It smacked rather obviously of a setup. Many editorials denounced the whole thing as a cheap publicity stunt. Every major newspaper in Tennessee criticized Dayton for staging the trial.

Unfortunately, once the media got the word out, things got out of hand. First, William Jennings Bryan, three-times Democratic presidential candidate, offered to help with the prosecution. This offered the Dayton boosters the opportunity for greater publicity than they had dared hope for. Next, Clarence Darrow, probably the most notorious criminal lawyer alive at the time, volunteered for the defense. Darrow had just come from a sensational trial in which he was successful in obtaining acquittals for two confessed murderers by arguing that they were not responsible because their behavior was determined by their heredity. Darrow's entry into the fray added to the sensationalism, and his zealous agnosticism transformed the trial from a small-town publicity stunt into a national confrontation between science and religion.

The trial began on Friday, July 10. By the following Friday, the trial was all but over, and the outcome was clear. The defense had lost the

case, Clarence Darrow notwithstanding. All that remained was to clear up a few formalities. But Darrow had other ideas, and Bryan was willing to meet the challenge. Darrow called Bryan to the witness stand, over the objections of Tom Stewart, lead prosecutor. Unfortunately for Bryan, his ego stood in the way of his objectivity, and he waived off his colleague's objections. Once Bryan was in his grasp, Darrow proceeded to grill Bryan about his religious beliefs — which had nothing whatsoever to do with the case at hand. Bryan affirmed belief in miracles such as Jonah living in the whale for three days, and Eve created from a rib taken from Adam. But when it came to the literalness of the days of creation, Bryan hedged, replying that they could have represented long ages. Although this exchange did not help to exonerate John Scopes, it did provide publicity for the antireligious views Darrow represented.

The third section of the book discusses the aftermath of the trial. Contrary to the popular legend, the antievolution movement gained strength after the trial. Darrow's outspoken antireligious views gave Bryan the status of a martyr when he died only five days after the trial ended. Mississippi and Arkansas soon had antievolution laws, and Texas and Louisiana barred the subject from textbooks used in their respective states. Although the movement never caught on in the North, it did not die. Both sides claimed victory, but neither side was defeated.

The distortion of the trial and its effects began in 1931 with publication of a book by Frederick Lewis Allen, *Only Yesterday*, in which Allen reflected on the happier days of the Roaring Twenties in contrast with the Great Depression. Allen attributed a great victory for Scopes and the defense, in line with the prevailing attitude among evolutionists. What he failed to note was that the Fundamentalists regarded it as a victory for their side. In reality, the trial was not decisive for either side, but merely a sensationalized confrontation in an ongoing conflict between two world views.

The play (1955) and movie (1960) marked the completion of the popular, but false, legend of the Scopes trial. As it turns out, both the movie and the play on which it was based, were actually not motivated by the Scopes trial. Instead, the play writers had in mind the anticommunist campaign of U.S. Senator Joseph McCarthy, and the threat it posed to personal liberties. They merely used the Scopes trial as a setting to make their point that attempts to limit speech were inimical to personal freedom. In view of their purpose, there was no real need to be con-

cerned about historical accuracy. Yet the play and movie have been the main source of "information" about the Scopes trial, with the result that the average American is sadly misinformed about the historical realities of the trial.

Two lessons from the story deserve mention. First, one should be cautious about believing everything he "knows." Much of what we "know" about the Scopes trial seems to be wrong. The same is probably true in other cases. It has been said that history is rewritten by those in power. Second, big egos make big targets. Bryan's overconfidence led him to take the witness stand for what seems to be no purpose other than to satisfy his desire for publicity. Bryan's experience is somewhat reminiscent of the experience of Samuel Wilberforce in his debate with Thomas Huxley, although it is likely that Wilberforce's story has suffered a similar distortion at the hands of those in power.

In summary, the book is highly readable, and attempts to present the trial from as unbiased a point of view as possible, although the author's bias does show through in a few places. I highly recommend the book.

NEWS AND COMMENTS

GEOLOGICAL SOCIETY OF AMERICA MEETING

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WHAT THIS NEWS NOTE IS ABOUT

This is a brief summary of some highlights of the Geological Society of America's Annual Meeting, held November 9-18, 2000 in Reno, Nevada. The authors attended the meeting and a cumulative total of approximately 100 talks out of over 3 000 papers presented. Abstracts for these talks are published in the GSA Abstracts With Programs 32(7).

SEDIMENTARY GEOLOGY

One of the geologic "fads" at the Geological Society of America annual meeting for 2000 was the "snowball earth" hypothesis proposed by Hoffman et al. (1998). Upper Proterozoic diamictites (conventionally interpreted as glacial tills) are widely distributed over continents and latitudes, both present and ancient. Equatorial paramagnetic indicators on multiple continents suggest the entire earth's surface was frozen at this time (thus the "snowball earth" concept). The excitement and debate over the new theory resulted in many papers, including computer modeling studies, identification of new outcrops (e.g., the Red Pine Shale by Crossey et al. [2000]), reevaluation of old sites, and debates about "cap carbonates" (carbonates found atop the diamictites in many localities).

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Stanley Awramik et al. (2000), for example, argued once again for a glacial interpretation of Kingston Range's Kingston Peak Formation. Steven A. Austin et al. (1994), R. Sigler (1998), and Steven A. Austin and Kurt P. Wise (1999) had previously interpreted these deposits as submarine landslide deposits based upon strong current indicators, huge megaclasts, slumping features, and the absence of autochthonous shallow-water carbonates and glacial indicators. Awramik et al., however, claimed the presence of such glacial indicators as "abundant" "drop-stones" and striated boulders as well as autochthonous carbonate. It seems that these claims need to be reexamined by Austin and Wise.

Another recurrent subject in the 2000 abstracts was the strong negative carbon-isotope excursion often found in the cap carbonates. Since sea water usually has C-isotope values only slightly negative (-4) and organic carbon is strongly fractionated (-20), the negative excursion is thought to involve a huge dump of organic carbon into the oceans (e.g., a methane "burp" as suggested by Martin J. Kennedy et al. 2000). According to Kennedy et al., the molar quantity of organic carbon necessary to produce the isotope excursion is on the order of magnitude of the amount of carbon necessary to cap the entire world with a thin carbonate. Cool (methane) seep sedimentary features are also similar to those seen in cap carbonates.

Yet another possibility might be that the initiation of the Flood (which Austin and Wise 1994; and Austin et al. 1994 tentatively place immediately below these upper Proterozoic diamictites) released huge volumes of pre-Flood organic carbon into the world's oceans. This might not only create the C-isotope excursion but possibly also force the precipitation of the so-called "cap carbonates." Perhaps the same mechanism is then also responsible for the simultaneous excursions in sulfur isotopes (Hurtgen et al. 2000) and oxygen isotopes.

Chris Baldwin and colleagues (2000) presented a novel interpretation of the Bright Angel Shales in the Grand Canyon region. McKee and Resser (1945) considered the shales a deepening offshore facies of the Tapeats Sandstone. Baldwin et al. now report evidences of shallow water, and even eolean deposition, and reports strontium isotope signatures of fresh water in these beds. In spite of the radical reworking of an iconic model (shallow rather than deep, dry in place of wet, and fresh for marine), there were not challenges from the audience.

Several GSA abstracts discussed newly excavated bone beds. Each of them described the bone as lying in a coarse conglomerate with long

bone orientation indicating deposition in a current. In each case, logs were present among the bones. One log acted as a current baffle during the deposition of the bed (and possibly facilitating the concentration of bones). This is true of a bone bed in the Upper Triassic Chinle Formation (Ziegler et al. 2000) and one in the Upper Cretaceous Judith River Formation (Larock et al. 2000).

Kevin Burke and Jeffrey Kraus (2000) reported on the remarkable extent of the mature Cambro-Ordovician sandstones. They estimate $15 \times 10^6 \text{ km}^3$ of sand deposited over North Africa, Arabia, and associated sedimentary basins in South America and eastern North America. This is equivalent to covering all 50 states of the USA with one kilometer of sand! These sandstones have been carved in one place to produce the famous city of Petra, and eroded in others to produce the massive sand dunes of the Sahara Desert. This sandstone unit has the uniformity, thickness, areal extent and distant source area which Austin (1994) suggests should characterize Flood deposits. Another example of sediments with broad areal extent uncharacteristic of the present (but expected in a global Flood) was reported by Andrew Webber et al. (2000) for Cincinnati sediments of mid-continental North America.

PALEONTOLOGY

Among the paleontology papers at a GSA meeting are usually some which introduce new revelations of biological design ("adaptation" in conventional evolutionary terminology). At the 2000 annual meeting, Tomasz Baumiller and David Meyer reported a design which allows stalked crinoids to align themselves to maximize food intake. The crinoids studied are found above wave base in the Great Barrier Reef. They need to continually and rapidly (in seconds) realign to respond to oscillating currents. Baumiller and Meyer found that the pinnules passively swivel due to loose, flexible ligaments aligned perpendicular to the axis and yet remain vertical in the current due to the shape of inter-element articulation and rigid spines aligned parallel to the pinnule axis.

It is usual among GSA's paleontology papers to report on remarkable examples of fossil preservation. As an example, two papers by Arthur Chadwick and Leonard Brand and students (Carvajal et al. 2000; Esperante-Caamano et al. 2000), following up on last year's initial report (Esperante-Caamano et al. 1999), described hundreds of whales preserved in a Peruvian diatomite. The lack of bioturbation and scavenging, and the remarkable preservation suggests a taphonomy quite unlike that

experienced by modern whales. This suggests these Miocene/Pliocene sediments were deposited under conditions of rapid deposition not found in the present. Stefan Bengtson (2000) reports on some remarkably well-preserved, phosphatized Upper Neoproterozoic and Lower Cambrian embryos which even seem to show cleavage patterns (see also Xiao and Knoll 2000)! Such embryos argue for the reality of the Cambrian explosion (preservation is sufficient to pick up soft-bodied forms that may have been there) and provide exciting specimens to paleontologists working out the origin of the animal phyla.

The current hot topic in evolutionary theory is "Evo-Devo" (pronounced EE-voh DEE-voh). The failure of megaevolutionary theory to explain the apparently rapid origin and subsequent stasis of animal phyla (the "Cambrian Explosion") has forced theorists to seek new mechanisms of organismal change. Developmental biology has been appealed to for evidence and theory (thus the new journal *Evolution & Development* and the same-named field, abbreviated "Evo-Devo"). There was an entire Evo-Devo session at the GSA with 14 papers, including one by Stephen Jay Gould, the abstract of which did not appear in the published Program. This special session, including four invited papers, was an attempt to synthesize developmental biology and paleobiology.

One of the invited papers was a review by Rudy Raff (2000). He reminded the audience that Ernst Haeckel's claim (e.g., see Pennisi 1997) that all animals develop through similar first stages is contradicted by the observation that extremely divergent steps occur *prior to* similar steps. He calls this a "developmental hourglass." He also reminded us of the extreme robustness of development (e.g., genome elements from a fly placed in a developing echinoid results in the animal initially developing as if it were heading for a fly/echinoid chimera, but ultimately adjusting and becoming a perfectly good echinoid). This suggests that development is designed to survive substantial perturbations in early growth. It also suggests that mutation is going to have a very hard time modifying organisms according to the "needs" of evolutionary theory.

Raff also reviewed a couple examples of echinoderm species (e.g., two similar species of the starfish genus *Patriella*) which have adult similarity, and yet have radically different early developments. This is rather difficult to explain in conventional evolutionary theory. Raff also claimed that multiple times among the echinoderms, identical larval forms have convergently evolved. The rapid origin of alternative developmental pathways indicated by these latter two examples may

be better explained by Todd Wood's AGEing (altruistic genetic elements) hypothesis (Wood, in review a).

Eric Davidson's (2000) invited Evo-Devo paper briefly reviewed regulatory genes and their theoretical impact upon evolution. Davidson argues that the differences among animal phyla are largely found in the regulatory gene network — both during development and in the adults. Davidson describes these regulatory networks as “hard-wired” into the organism's genome. He claimed to deliberately use an analogy from humanly designed electronics systems because of the mindboggling complexity and “if-then-else” statement-type logic of the system. Davidson focused on outlining the incredible complexity of what he calls the “Type I Embryonic Process” which results in the production of larval forms in many bilateria.

A recently suggested and popular construct in evolutionary theory for the origin of the animal phyla is the development of “set aside cells” in larval forms as a place to evolve adult animal complexity while the larval form supports both itself and these new cells. It is difficult to explain how such complexity is generated by selection in such cells, and it is difficult to explain why natural selection would not select against the organism which possessed these energy-sapping (i.e., parasitic) cells.

Davidson alludes to yet another problem with this hypothesis in that the level of complexity in the regulatory system of these set-aside cells is literally orders of magnitude greater than that of the “Type I Embryonic Process” which produces the larvae. Note also that all this must occur before the Cambrian Explosion. Davidson repeatedly stressed the fact that “There is no simple bilaterian.”

Early evolutionary development of complexity was a repeated theme in the Evo-Devo talks. Colin Sumrall (2000) argued that the 2-1-2 ambulacral (referring to rows of tube feet) symmetry (i.e., in some sense the most complex ambulacral symmetry) was the first echinoderm symmetry and all other “simpler” symmetries found in the fossil record and the present are developmental modifications (simplifications) of that more complex theme. Gould shared his conviction that the earliest bilateria must have had the full complex of *hox* genes, and any deviation from this has been more or less degeneration.

Abundant homoplasy (evolutionary parallelisms and reversals), with its attendant evolutionary consequences of convergent, parallel, and mosaic evolution was yet another theme which resurfaced repeatedly in the Evo-Devo talks at GSA. Although Sumrall's hypothesis seems to

make some sense of the echinoderm disparity, it also requires the repeated, independent (convergent) evolution of the various reductions of that symmetry. Here then is an example of a hypothesis which suggests a phylogeny in a group which has been hitherto a phylogenetic nightmare, but which now requires a mindboggling amount of convergent evolution (i.e., the kind of ubiquitous homoplasy predicted by Wise's (1998) mosaic network hypothesis). Other examples of homoplasy included Raff's (2000) reminder that echinoderm larval forms evolved multiple times among the echinoderms.

Yet another repeated theme in the Evo-Devo talks was developmental bridging of fossil record gaps. Megaevolutionists believe that many transitions between major animal groups might have occurred in larval or early adult development. If so, then true morphological intermediates might have only been realized in larval forms. This, in turn, would explain the lack of (adult) stratomorphic intermediates (interpreted as "transitional forms" by evolutionists) in the fossil record. The divergence of developmental pathways from a common ancestor in echinoderms (Sumrall 2000) is an example. The absence of interclass and inter-order (adult) echinoderm stratomorphic intermediates could be argued to be due to transitions occurring in early developmental forms which are expressed in adults as abrupt and large changes. On the other hand the multiple origin of echinoderm larval forms in echinoderm genera (mentioned by Raff) and the multiple origin of developmental pathways in echinoderm higher groups (mentioned by Sumrall) seems to make this hypothesis highly unlikely.

Robert Carroll (2000) provided another more dramatic example by showing the strong similarities between several fossil larval forms of the extinct labyrinthodont amphibians (known as branchiosaurs) and modern salamanders and frogs. Thus, although there are no adult stratomorphic (stratigraphic and morphological) intermediates between labyrinthodonts and modern salamanders, larval labyrinthodonts (branchiosaurs) function in that capacity. However, mosaic combinations of salamander and frog morphologies among the branchiosaurs make the actual identification of stratomorphic intermediates difficult. If one assumes this scenario to be true, there are repeated convergences of the direction of developmental ossification. Such convergences seem to render the process improbable.

Yet another example was provided by Graham Budd and Joakim Eriksson (2000). Lower Paleozoic arthropods have anterior mouthparts

rather than ventral mouthparts as in modern arthropods and onychophorans. Yet, onychophorans begin development with anterior facing tissue which develops into mouthparts. This suggests that the common ancestor had anterior mouthparts. This hypothesis is attractive because several worm groups have anterior mouthparts and so can function as an evolutionary ancestor. On the other hand, none of these groups have the segmentation of the Onychophora and Arthropoda, suggesting that segmentation and probably jointed appendages are convergent characters.

CLIMATOLOGY

Andrea Bair (2000) documented an increase in hypsodonty (high-crowned teeth) and diversity among fossil lagomorphs (e.g., rabbits) in the North American Miocene sediments. So, at about the same time and on the same continent that horses (see MacFadden 1992) and camels and other mammalian herbivores are (convergently) increasing in hypsodonty and diversity, rabbits and pikas are doing the same. In fact, Bair claims hypsodonty arose 5 different times in the pikas alone! Austin et al. (1994) suggested that the selection pressure for hypsodonty is a consequence of the post-Flood spread of grasses at the expense of broad-leafed plants during the cooling and drying period on the post-Flood earth.

As the climate of the post-Flood earth converged on a modern climatic regime, hot dry regions developed in the earth's low latitudes. The likely drop in partial pressure of carbon dioxide through the Flood (Austin et al. 1994) combined with the dry heat stress in low latitudes is likely to have favored the spread of grasses with photosynthetic pathways adapted for tropical (C_4) and desert (CAM) environments. This in turn is likely to have encouraged the proliferation of such grasses at the expense of broad-leafed plants. In the Paleontological Short Course held on the Sunday preceding the GSA meeting, Thure Cerling and J.R. Ehleringer (2000) reported that ungulate teeth and fossil soils first pick up carbon-isotopic evidence of C_4 photosynthesis in Miocene sediments. The oldest known fossil C_4 plant is also found in Miocene sediments. It is also in Miocene sediments that a substantial increase in hypsodonty is found in a variety of herbivores. It may be in the dry post-Flood times (during the brief period of deposition of Miocene sediments) that C_4 and CAM photosynthesis arose and spread among the plants. Such alternate photosynthetic pathways are now found in

15 different dicot families and 3 monocot families, including about 5000 grass species (Cerling and Ehleringer 2000; see also Wood [in review b] for more discussion). Such widespread and rapid origin of complexity is better explained by Wood's (in review a) theory of altruistic genetic elements (AGEing) than conventional evolutionary theory. AGEing is also likely to be the mechanism for the simultaneous explosion in diversity observed in lagomorphs (Bair 2000), horses (MacFadden 1992), and other herbivorous animals.

ARCHAEOLOGY

Robert Schoch and John West (2000) gave an update of their controversial research on the Egyptian Sphinx. Based on early Old Kingdom repairs on the Sphinx and early Old Kingdom quarrying that diverted surface water from eroding the Sphinx, the Sphinx is given a pre-dynastic age (Schoch and West 1991). The water erosion of the Sphinx and other pre-dynastic structures (including the core of the Dahshur Pyramid) suggests that pre-dynastic Egyptian climate included high precipitation rates, as expected in the post-Flood climate proposed by Michael Oard (1990) and modeled by Larry Vardiman (1994). At the same time, the pre-dynastic date for the Sphinx suggests a pre-dynastic date (and thus deeper time) for sophisticated culture in Egypt, as would be expected of culture-capable people dispersing from the Tower of Babel.

James Teller et al. (2000) proposed that Noah's Flood is to be identified with the inundation of the Persian Gulf. Dunes in United Arab Emirates are composed of carbonate grains derived from the floor of the Persian Gulf at a time when the Gulf was water-free. Following formation of these dunes, the Gulf was filled with water from the ocean — conventionally dated between 14,000 and 6,000 y.b.p. Teller et al. suggest that the sea level rise might have exceeded 1 km per year at times — so fast as to require boats to rescue people stranded on islands. Although geographically superior to recent proposed identification of Noah's Flood with the flooding of the Black Sea (Ryan and Pitman 1999), this explanation fails to explain a) the breaking up of the fountains for the great deep (Gen. 7:11); b) unusual rain (e.g., "windows of heaven" vs. rain in Gen. 8:1); c) the great wind (Gen. 8:1); d) the falling of the waters (e.g., Gen. 8:5); e) the covering of all the high hills under the whole heaven (Gen. 7:19); f) the death of all humans and animals on the face of the earth (e.g., Gen. 7:23); etc.

Stephen B. Mabee et al. (2000) reported early results on research into the famous Nasca Lines of Peru. They reported on two locations where ancient aquifers, habitations, and cemeteries are associated with fresh water springs, which are in turn located along earthquake faults. In each case, nearby Nasca Lines in the form of triangles actually point out the fault trace as it extends across the desert towards the next pass and associated water sources. The researchers are planning to test the hypothesis that the Nasca Lines were constructed so that these people could find water in the desert of Peru. This explanation is not only reasonable (vs., e.g., an alien origin a la von Däniken [1971]) but also suggests that the ancient Peruvians might have had some geologic acumen, capable of creating hydrology and fault maps. This is consistent with the biblical inference that humans have been intelligent and capable of high culture from their origin.

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