The 23-Hour Day

III. THOUGHTS ON THE SCIENTIFIC ATTITUDE

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It is easier to raise questions than to provide satisfactory answers for them. So goes a critical truism familiar to all educators. It could be argued, of course, that questions have a stimulating value in themselves, independent of the answers that may (or may not) be given. But some persons will still feel that answers are of surpassing importance, and in any case they are certainly to be desired.

In two preceding articles I have considered some suggestions as to how a scientific attitude should affect our approach to problems in religion, and some criticisms of answers that have been given by others.[1] Now it is only fair that I should anticipate and reply to the objection that those articles have not shown clearly what kind of answer I think should be given to the questions I have raised.

THE POSSIBILITY OF PROOF

One of the most powerful tools of logic is the method of counterexample, the use of which may be adequately illustrated for our purposes as follows.

Suppose I have noticed that 5 times 5 equals 25, and 6 times 6 is 36, and have therefore wondered whether it is true as a general proposition (which I call A) that "whenever I square a number, its last digit reappears as the last digit of the answer." If I were dealing only with a finite set, there would be a straightforward way to find out; for if there existed only twenty "numbers," I would need only try the other eighteen cases to ascertain the truth or falsity of A. But since there are in reality infinitely many numbers, and I could never test every case, one of two things may happen. First, I may try 10 (and get 100), 16 (256), 31 (961), and similarly successful cases.

As long as this happens, the possibility is at least left open that A is true; but since I have not tested all cases, it may yet turn out that A is false. Therefore I can never prove A by any list of examples; and if A *is* true, this can be proved only in some other more sophisticated way. The second possibility is that I may happen to try 2 (and get 4), in which case I need look no further: a single counterexample suffices to prove the absolute falsity of A as a general, all-inclusive proposition.

This illustration suggests to me that the method of counterexample has an important role to play when we are attempting to decide what general statements we can truthfully make about a subject like the history of the Earth. When we first have a vague idea, we will try it in a few places where it has a reasonable chance of success, and thus be encouraged to formulate it carefully into a definite and concise general proposition. But then we will not continue looking for easy cases to demonstrate its truth; in the language of my example, we would not pick a million numbers all ending in 0, 1, 5, or 6, and then publish a glowing report of how successful the theorem was. We ought instead to pick deliberately the most difficult case, perhaps the one most different from those we have already tried. One should hope to be able to say, "This is the most stringent test I can devise at the moment; if my theory is going to fail or prove subject to limitations, this seems the most likely place." If the theory passes this test, it will not yet be proved true, but the likelihood of its truth will at least be much more convincing. And if it fails, we may thereby avoid waste of time and effort and be able to resume searching for a better theory.

A PROMISING PROBLEM

It is in this vein that I wish to consider what might be called the era of the 23-hour day. I suspect that those with a thorough knowledge of geology will know of more stringent tests than this for creationistic models of Earth's history. But this particular test seems to me to have the advantages of being straightforward and relatively easy to understand, and of going directly to the heart of the matter.

With the exception of carbon-14, radioactive age determinations are made on igneous or strongly metamorphosed rocks — that is, on inorganic material. This leaves room for heated debate as to just how closely some fossils, in adjoining sedimentary strata, are associated with the dated rocks. There is a three-way split into (*a*) those who accept both dates and association (usually labeled "evolutionists"), (*b*) those who argue against the association in order to allow old rocks but no life before a recent divine fiat

("old-Earth creationists"), and (*c*) those who argue against the validity of all radioactive dating methods in order that the rocks as well as the fossils can be regarded as recent ("young-Earth creationists"). These labels are not entirely clear-cut; there would be some, for example, who believe in a long history of life on Earth but a recent special creation of mankind.

On the other hand, radiocarbon and amino-acid dating techniques,[2] which deal directly with organic material, are based on processes with relatively short half-lives. Again, there is debate between some who argue against the dating methods in order to retain a date for Creation around six thousand years ago, and others who feel they can allow life to extend back some tens of thousands of years in order to explain this data while remaining basically creationistic in their outlook.

We might cut away many extraneous issues and face the problems of any creationistic model most bluntly if we had a class of data that deals *directly* both with organic life and with ages in hundreds of millions of years. The 23-hour day would appear to be such a case, and to it I now direct attention. In order not to lose sight of the forest while examining the trees, I will record most of the scientific details in a series of appendixes (even though the considerations there are mainly elementary) and give here only a very brief summary.

The rotation of Earth on its axis is not quite steady, but is slowing very gradually as a result of friction connected with the ocean tides. If this process had been active at about the present rate for a hypothetical period of 200 million years, its accumulated effects would have been enough to lengthen the day from 23 to 24 hours. When each day was shorter, there would have been more days in each year (Appendix A).

It has recently been found that a number of marine creatures such as clams and corals build into their skeletons a permanent growth record very similar to tree rings. Experimental studies of modern specimens indicate that daily, monthly, and annual variations in growth may all be recorded (Appendix B).

But while modern specimens show 360-370 days per year, fossils are found that yield counts of 400 and more. The hypothesis of a long history of tidal friction comparable to the present amount then dates a specimen with 380 minor growth bands per major one as being about 200 million years old, 400 days per year as 450 million years old, and so forth. Paleontologists report good agreement between these dates and the ages assigned to the fossils by the usual stratigraphic methods (Appendix C). This would appear to constitute confirmation, by a completely independent method, for

the very great ages assigned to life on Earth in the evolutionary theory — and so much criticized by creationists as unreliable.

CONFLICT AND RESPONSE

Now that the problem has been thrust on our attention, what shall we present in the way of explanation? Let us consider the pros and cons of several possible attitudes.

First, some might entertain the thought that the data have been irresponsibly gathered or reported and are simply not what they appear to be. There is always a chance of this being so in any particular investigation, at least in the early stages. But I must say that my own study of the original articles has not given me any reason to think that such a thing has happened in this case. At the very least, we must take this as the best data available on the subject until any more are found that would contradict it; and on this basis we must decide what to do with it.

Second, some will say, "I don't care; this doesn't bother me; the Devil is just making these things up and trying to deceive us; but I'll stick with the Bible." This position has in its favor that it seems to provide comfort for some people. There is also, at least on the surface, a certain admirable consistency in stubbornly clinging to this one authority, come evidence or high water. Such a person may be thought hopelessly backward by many others, but perhaps that should not influence us. After all, being right must certainly come before being popular. Yet, at the practical level, one cannot ignore the fact that such an attitude of obscurantism will effectively eliminate the possibility of evangelizing educated people. And at the philosophical level this position leaves unsaid that one can only stick with what *he thinks* the Bible means. So we return to the problem of *how* one may know he has the correct interpretation, to the exclusion of others. And we are right back to the matter of examining *evidence* for beliefs, which is exactly what we are being asked to do now with the data on the 23-hour day.

Third, there is the possibility of saying (if one had not already done it long before on the basis of other data), "This is conclusive; no viable alternative remains — I'll just have to write off any possibility of creationism." This would give one the satisfaction of joining the intellectual majority, and we must not underestimate the very strong arguments that could be made in favor of this position. But, in its pure form, such an attitude shows some misunderstanding of science, which seldom views things quite so definitely. The careful scientist with typical inclinations toward evolution would be saying, "This certainly seems to fit nicely into my model, and

indicates some definite difficulties with the other one" — or at least he would if he were acquainted with cautious and scientifically responsible creationists. But some creationists have a penchant for committing themselves irretrievably to one or another very narrow and specific model of how Creation had to happen; and these models the scientist might justifiably consider to be definitely disproved by his new evidence.

Fourth, perhaps we could come up with a new and improved type of creationist model that would account for the new data. This is certainly a very desirable and scientifically legitimate procedure. It is also difficult, and we cannot be assured of any early success — the more obvious ideas immediately encounter difficulty. But we have good theological as well as scientific grounds for this approach. The prophet Jonah and William Miller are two outstanding examples of people who had to radically revise their models of how God deals with men — the old model in each case was an approximation to truth, not truth itself, and a better approximation became necessary. "Prove all things; hold fast that which is good."[3]

A variety of models for a Noachian Flood might be thought to include reasons for a slowing of the Earth's rotation. But if this occurred suddenly, there should be only two values — pre-Flood and post-Flood — for the number of days in a year, whereas the observations seem to indicate a continuous variation. On the other hand, an attempt to build continuous variation into a Flood model leads to a threefold problem:

1. If an appreciable part of the slowing is pre-Flood, then a great deal of change and deposition of fossils is being attributed to that period, and this really removes the Flood as a cause anyhow.

2. If the slowing is said to be continuous rather than sudden, and yet limited to a Flood duration of about a year, then none of the intermediate values for number of days per year would have lasted long enough to be recorded by the fossils, and we return to the problem that only two values should be observed.

3. If the slowing is mainly post-Flood, then the major part of the geologic column would have to be laid down, not during the Flood, but over a period of many years after it. This does not fit well with the usual idea that the waters (and violent events in general) were largely abated by the end of the first year. It also leaves as a mystery why the present rate of slowing (which extends at least 2,500 years back, well over halfway to Ussher's date for the Flood) should be so much smaller (perhaps a million times) than the immediate post-Flood rate, which must have persisted for many years (perhaps a hundred at least).

Thus I must admit that at present I have no satisfactory model to propose, nor can I readily imagine the existence of a workable model, even though I would still like to hold open the possibility that such a model might yet be discovered.

Fifth, and not to the exclusion of the fourth, I personally feel that this is one of those gray areas of uncertainty in which I would be wise to refrain from polemics on any side. I must take this evidence and examine it honestly, and give it some weight relative to all other evidence available to me. I may admit that I am not entirely satisfied, but neither science nor theology will allow me to simply ignore even one piece of available evidence. I will attempt to arrive at the most nearly satisfactory conclusions, but they will be admittedly tentative, and may even be phrased in terms of relative probabilities for several models of what has taken place. In other words, I frankly hold suspended judgment.

This may be a disappointment to some: "You promised answers at the beginning, and now you're just leaving us vaguely in midair again with this so-called suspended judgment." But that is precisely my point: I believe that suspension of judgment *is* the appropriate answer for the present time on many subjects. More than this, I think that sometimes it is the *only* reasonable answer. And it must not be just a show of suspended judgment, followed by a muttering under the breath that "in my heart I know it can't be that way." I think we must say in all honesty not only that this piece of evidence appears to point strongly toward a very long history of life on Earth, but that it actually compels us to consider seriously the probability that there is in that model some truth after all.

Our fervent desire for a definite and final answer cannot provide that answer. Neither can our most sincere longing that the answer turn out to be A instead of B make it so. These desires must be consigned to second place; honesty and candor in the search for Truth must come first.

ACKNOWLEDGMENTS

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APPENDIX A

The Earth as a Clock

By any ordinary standard, the Earth is a remarkably accurate timepiece. Its daily rotation on its axis is so steady that clocks may be set by it within small fractions of a second from day to day, by observation when some convenient star appears to pass directly overhead. Special telescopes are mounted just for this purpose in such places as the U. S. Naval Observatory in Washington, D. C. Long series of such astronomical observations lead to the conclusion that the present mean tropical year consists of 365.242199 mean solar days.[4]

But the Earth-clock is not perfect, nor should we expect it to be. When compared with modern atomic clocks, the Earth is found to be slightly erratic, running as much as half a minute behind or ahead of its average rate. Records of eclipses also allow us to check on the Earth's rotation well over two thousand years into the past. Both lunar and solar eclipses occur in definite cyclic sequences and can be predicted in advance. But predictions based on past eclipses tend to be just slightly behind the actual occurrence of new eclipses. After allowance for short-term fluctuations, this can be accounted for by a gradual slowing down of the Earth's rotation, so that a day is about two thousandths of a second longer now than it was a hundred years ago.[5] The total amount of time "lost" in a century is about half a minute, and in a millennium nearly an hour; in 5,000 years the Earth would be almost a day "behind" where it would be if it had kept rotating at the original rate. (The reader with a background in mathematics will recognize that each small increment of rotation rate will make a contribution to "total time lost" which is proportional to how long ago it occurred. Integration of these contributions results in quadratic dependence on total time elapsed, so that the time lost in a millennium exceeds that lost in a century by a factor of 100 rather than 10.)

There are two general ways in which the rate of rotation of any object may be changed. The first is exemplified by the ice-skater's trick of extending or retracting his arms while spinning. Application of the law of conservation of angular momentum requires that whenever the parts of a body are rearranged to reduce its moment of inertia (a measure of how far its mass is located, on the average, from the axis of rotation), this will automatically be compensated by an increase in angular velocity (rate of rotation) just sufficient to leave the product of these two quantities unchanged. There have been speculations that the Earth, if originally formed by accretion, would have had a greater moment of inertia which was reduced to its present value by melting and formation of a differentiated core. The resulting increase in angular velocity would appear to be opposite to what is needed to explain the data with which we are concerned.[6] However, the most recent analysis[7] indicates that the long-term average acceleration does involve some positive "nonfrictional" component whose mechanism is still uncertain; this cancels part of the larger negative frictional effect described in the following.

The second way to affect the Earth's rotation is to have it acted upon by other celestial bodies, for its angular momentum may change if there is a torque (a combination of forces acting to bring about a turning motion) applied from outside

itself. The most important such influence comes from the Moon, and may be understood in terms of FIGURE 1. The Moon raises tides in the ocean, and to a lesser extent in the Earth's crust itself. (It has recently become possible to measure directly the tidal distortion of the Earth's overall shape by its effect on satellite orbits.)[8] If these tides were located directly underneath the Moon, they would not give rise to torque; but the presence of friction allows the Earth's rotation to carry the tidal bulges somewhat ahead of where they "ought" to be. The Moon can then pull back on the nearer tide and thus slow down the Earth. The angular momentum given up by the Earth is not lost, but is transferred to the Moon. The result is that the Moon moves farther out from the Earth and takes longer to revolve around it.

Meanwhile, the Earth's revolution about the Sun continues unabated (except for a relatively minor effect of the solar tides, which would tend to lengthen the year); so the number of days per year and the number of months per year both slowly decrease. Also, it turns out, the fractional change in the length of the day is greater than that of the month; so the number of days per month decreases as well. If we look to the past rather than to the future, we should expect to find more days per month and per year.

If we were to assume that the known present rate of slowing down is comparable to that which has acted in the past, we would predict that it would have been something like 200 million years ago that the day was only 23 hours long, and that it would take a little over 380 of these short days to fill a year. This prediction is arrived at by extrapolation and must be used with due caution. We cannot dismiss it out of hand as completely meaningless, however, just because of a prejudice against anything "uniformitarian." This is simply one hypothesis that deserves to be tested along with any others we may formulate.

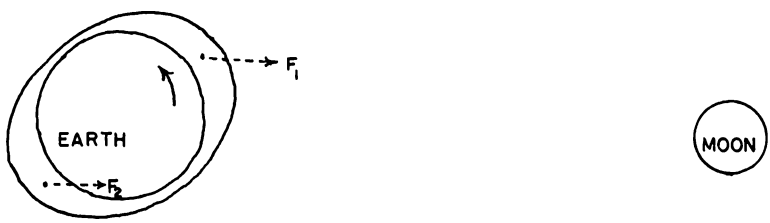

FIGURE 1: Mechanism for slowing the Earth's rotation. Tides raised by the Moon are carried forward from the sublunar and antilunar points by the Earth's rotation. The Moon's force of attraction, F_1, for the nearer tidal bulge is slightly greater than F_2. Since these forces are applied on opposite sides of the Earth, their difference constitutes a torque in the clockwise direction.

APPENDIX B

Marine Animals as Calendars

Living organisms reflect the conditions of their environment in their own health and growth, but it is somewhat the exception for a permanent record of environmental fluctuations to appear in the hard parts of either plant or animal. Annual growth rings in trees have been known about long and widely; but only recently has detailed study been made of corals and mollusks whose mineral deposits in reef or shell show a repetitive banded structure.

An interesting experimental study was carried out by Pannella and MacClintock in 1965-67[9] on the bivalve *Mercenaria mercenaria.* Over a hundred live clams were collected at low tide near Woods Hole, Massachusetts; their shells were notched with a file and numbered with printer's ink. They were then replanted in the intertidal mud just west of Duck Island. After 368 days, and again after 723 days, several specimens were recovered and killed so that the growth of their shells could be studied microscopically.

The shells had grown as much as fifteen millimeters along the ventral margin, and thin sections taken from the shell clearly showed a banded structure, much like tree rings, with spacings of a few microns. Considerable information seems to be recorded in this structure. First, a simple counting of "rings" indicates that they represent a daily cycle of activity and rest, for a number of specimens showed between 360 and 370 growth increments when collected after 368 days, and between 720 and 725 when collected after 723 days. This idea is also supported by comparable agreement between the number of growth increments from the notch to points of sudden narrowing of the bands, and the number of days from transplantation to December 18, 1965, or January 10, 1967, these being the dates of the first major freezing spells of the two winters.

Not only were daily patterns of growth observed; the authors also reported bidaily, semimonthly, and annual periodicities. The annual variations are easily recognized, for during winter the daily layers are one to seven microns in thickness, whereas they increase to ten to sixty microns in summer. Fourteen-day cycles are also expressed by changes in thickness of daily increments; and these cycles alternate in strength to make a monthly cycle.

The reasons for these cycles are far from fully understood, but (with the exception of the bidaily rhythms) it is not at all surprising that they should occur. Variations in light and/or warmth seem to provide a stabilizing mechanism for approximately daily metabolic rhythms in a wide variety of organisms, including man; there is a large body of literature on this subject of "circadian rhythms."[10] Light might seem the more likely stimulus for subtidal life, where the temperature is kept nearly constant by the ocean. The same factors vary annually; in this case we might expect stronger temperature effects, both directly as they influence the activity of the organism in question, and indirectly as they influence its food supply. But the reduction of total hours of daylight in winter could well have similar effects. Some experimental work is being done to elucidate these mechanisms.[11]

The food supply of subtidal and intertidal animals should also be strongly de-

pendent on the tides. There are two major reasons, of comparable importance, why the level and range of the tides vary from day to day. First, at new moon and full moon, the Sun cooperates with the Moon in raising tides, making them about 40 percent larger than they would be from the Moon's influence alone. At half moon, the Sun and Moon oppose each other and tides are weaker. These neap tides occur approximately every 14.8 days (half a synodic month) and correspond to reduced activity and narrower growth increments in the clams; the stronger spring tides between may bring more food within range.

Second, the Moon's orbit about the Earth is not circular; when it is closest (at perigee) its tide-raising effect is about 35 percent larger than when it is farthest away (at apogee). Thus there is also a 27.3-day (sideral month) cycle in tidal strength, and this too is reflected in clam growth, mainly through an apparent alternation in strength of the 14.8-day cycles. (However, it has also been proposed[12] that the animals were just more interested in the opposite sex at full moon.) The growth pat-

terns must not all be expected to look alike, because the Earth's rotation around the Sun means that in the course of a year there will be not just half as many monthly cycles as there are semimonthly cycles, but one extra as well; that is, 27.3 is not exactly twice 14.8. But these statements are not exact either, because the Moon's orbit is not stationary in space, and the direction to apogee rotates around the Earth once in 8.8 years. All in all, the tides are a fascinating — and very complex — subject.

Interesting though these questions are, for our further argument it matters only that daily, monthly, and annual variations do occur and have been correctly recognized. In fact, a strong point of these arguments is that they depend not on the exact details of the mechanism by which such cycles are produced, but only on our being convinced that the cycles actually occur.

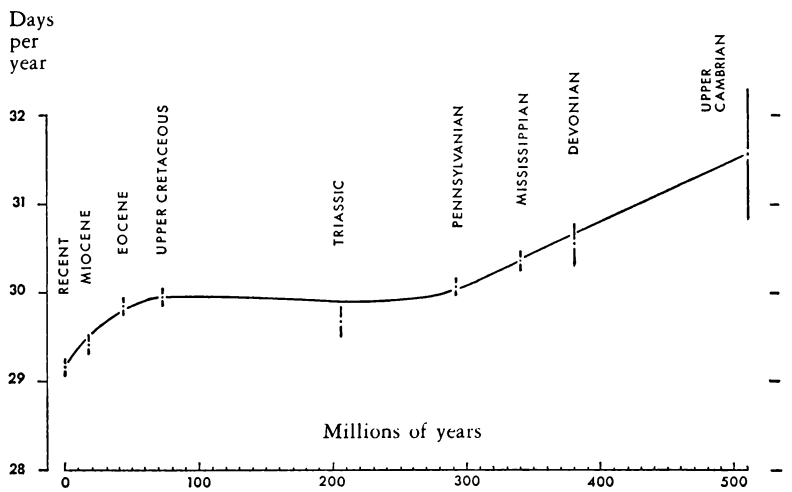

FIGURE 2: Variation in length of the synodic month, from Pannella, MacClintock, and Thompson.[17] The horizontal axis represents standard "geological age." The error bars show "standard error" (expected standard deviation of the mean) for each set of counts.

APPENDIX C

The Changing Calendar

The study by Pannella and MacClintock (described in Appendix B) was largely motivated by a new line of evidence in the field of paleontology, beginning in 1963 with an article by Wells.[13] It had long been known that certain species of coral showed annual variations in growth, and that certain specimens showed fine ridges on a much smaller scale between the annual bands. Wells put some modern specimens under the microscope, found that he could count about 360 small ridges per large one, and concluded that they probably represent daily growth variations. He then obtained some fossil coral showing similar structure, and found that he could count up to 400 or more small ridges per large one. The age of such a fossil could then be estimated by extrapolating the Earth's present rate of slowing and by asking when there would have been that many days in a year. And, remarkably, this estimate was comparable to the age as determined by standard geological methods based on the stratum in which the fossil had been found.

This process is open to the criticism that the investigator, having a preconceived idea of the result, might tend to count as many ridges as he expected. In order to eliminate this possibility of bias, Runcorn[14] proposed using the surface of a coral specimen for a diffraction grating. The periodicity of the reflecting surface determines the angles at which light will be preferentially scattered. The measured angles then provide an independent check of the ridge count. This method has its own technical difficulties, of course, and as yet I have not seen quantitative results from it to know whether it will support the counts by Wells.

Wells' work was soon followed by recognition and counting of monthly bands on corals by Scrutton,[15] and of daily, monthly, and yearly bands in bivalves by Berry and Barker.[16] A further article by Pannella, MacClintock, and Thompson[17] summarized data on the number of days per month found by a count of over twenty thousand individual daily bands in two dozen specimens. These specimens were mainly bivalves, but included a Pennsylvanian cephalopod and a Cambrian stromatolite. The results are presented in FIGURE 2. The first notable conclusion from this data is that the rate of slowing appears not to have been constant. Since the amount of tidal friction depends strongly on the extent of shallow seas, or perhaps on the existence of the Antarctic ice shelves,[18] we are led to interesting speculation about whether changes in the rate of slowing can be understood in terms of continental drift histories.

The second conclusion, more pertinent to our interests, is simply that the evidence for continuous change is very strong. The Pannella study presents data in sufficient detail that the reader can assess by his own standards the statistical significance of the counts. I have used a common standard test, the t-test,[19] to analyze the data. This test indicates less than one chance in a billion that the Recent and the Pennsylvanian specimens, for example, could give counts as different as they do if the true mean counts were really the same. Thus, as statistics go, one would say it is virtually certain that the modern and the fossil specimens give truly different counts.

The same test also indicates less than about 13 percent probability that Cretaceous and Pennsylvanian counts are not truly different, 3 percent for Pennsylvanian vs.

Mississippian, 6 percent for Mississippian vs. Cambrian, and so on for other possible comparisons. The conclusion that the differences are significant is strengthened by the current experimental studies of Clark,[20] who finds that "missing growth lines account for all scatter in the data, so that the maximum, not the average, line count is most representative." Thus, if the bands represent daily and monthly variations in growth, as appears most reasonable, animals have been growing on Earth in several eras with different numbers of days in the month or year, each era lasting at least long enough to be recorded by the fossils.

APPENDIX D

To Be Specific

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Although this information is subsidiary to the principal conclusion of my article, some may still wish to know what probabilities I assign to various models on the basis of my study. As to whether a divine Creator is responsible for the origin of life or whether life resulted from random accidental associations of molecules, I feel that the first idea provides a much more satisfactory explanation than the second. But as to how the Creator worked, I am much less certain.

For a variety of reasons, mainly outside the scope of this article, at present I assign a rather low probability to an age of 6000 $\pm$ 100 years for the biosphere. Evolution as commonly understood is not the only alternative, and it certainly has serious problems itself. So I still assign enough likelihood to an age of a few tens of thousands of years to retain a lively interest in such models.

But also I see an appreciable probability that somehow our exegesis has failed, and that the history of life on Earth must be measured in millions of years. I do not really consider the idea attractive; yet I must entertain the possibility that some day God himself might be explaining to me how this could be so. If that should ever occur, I hope I would not be offended, or express any bitterness that he had allowed me to misunderstand or that he had not done it all in the way I thought he should.

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