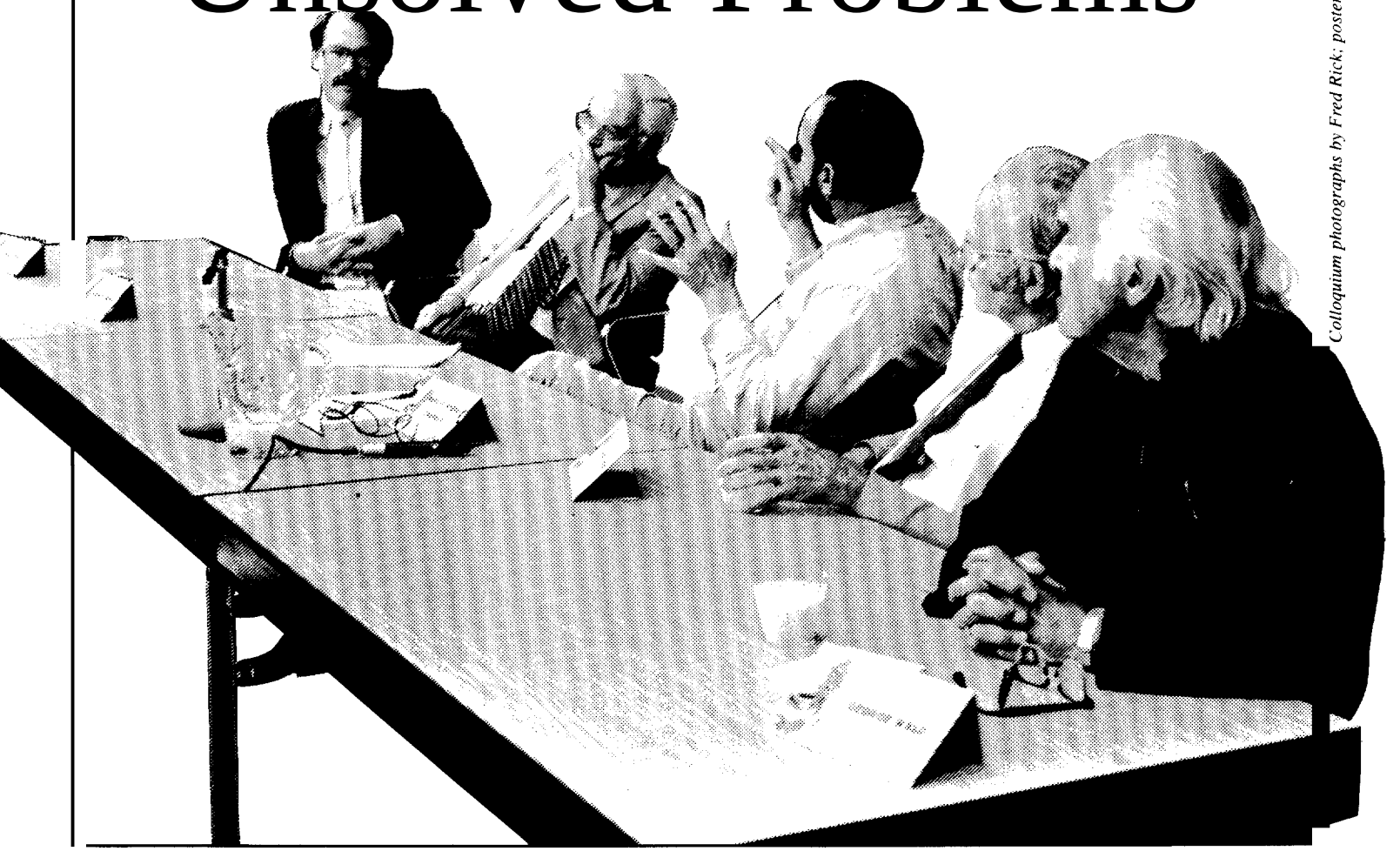
# Unsolved Problems



*Colloquium photographs by Fred Rick; posterizations by Chris Lindberg.*

## *A morning of discussion moderated by Mark W. Bitensky*

This morning we have the very pleasant opportunity to continue learning from the four dedicated students of biology who lectured yesterday on unsolved problems in the science of life. George Wald recounted the litany of anomalies that characterize the progeny of the big bang and introduced a deus ex machina—mind itself—as a driving force in evolution. David Hubel described what is known about how the detailed visual features of movement, form, and color are analyzed by the occipital cortex. John Sepkoski convinced us that extinction, like speciation, must be regarded as an integral part of evolution, playing the critical role of "making place" for newly evolving species. And Frank Drake projected a cosmos full of life and intelligence and with marvelous humor described efforts to communicate with that intelligent life.

I have consulted with our guests, and they have to a man agreed to a full and free-flowing discussion. I request only that questions and comments be clear and brief. Let us begin.

**Audience:** I have a question for Frank Drake. What countries are searching for extraterrestrial beings?
**Drake:** Two countries are making major effort—the United States and the Soviet Union. The Soviets have been searching now for twenty years. In fact, for a long time they were the only people searching. One of their projects, which is based at the Lebedev Physical Institute in Moscow, uses an array of about five radio-frequency receivers placed across the Soviet Union. A similar network is operated from the Gorky Research Radiophysical Institute. Both institutions have, until recently, been looking for short but powerful radio-frequency pulses, a type of signal very different from what we Americans are looking for. They recognize, as we do, that one of the really difficult aspects of a search is selecting the search frequency. Their way of finessing that problem is to look for short pulses, which appear on all frequencies. Their hope is that the extraterrestrials are thinking the same way and are transmitting short pulses.

Now the problem with short pulses is that human activities-operating cars and motorcycles, for instance—produce lots of them. So the Soviets look for short pulses that are coincident in an array of widely separated telescopes. If a pulse is cosmic, it will appear at all stations, but if it is interference, it appears only at one.

So far the Soviets have detected two interesting sources of coincident short pulses. One is the sun, and nobody had known before that the sun emits short radio-frequency pulses. The other was an American reconnaissance satellite that transmits information in the form of big, short radio-frequency bursts over a broad and variable band of frequencies to hinder reception by unfriendly receivers. But the Soviets did pick the signal up, and it got them very excited until they were told what the source was.

One of the problems with the Soviet program is that their small antennas can detect only very strong signals. In fact, to be detected by their system, a source at a reasonable distance of 1000 light years must have a luminosity equal to that of the sun. So the Soviet search will detect only those civilizations with capabilities well beyond those of earthlings, and for that reason the Americans don't think it is very effective.

The Soviets are also building a 70-meter steerable, parabolic radio telescope on a mountain near Samarkand, which is to be used not only for conventional radio astronomy but also in a program similar to that of the Americans.

I should note that Canada, France, the Netherlands, and Australia have also carried out searches, but theirs have been less extensive than the Soviet and American efforts.

**Audience: I** have a question for Professor Hubel. What chemicals are involved in visual perception, and are the transport mechanisms electronic or ionic?
**Hubel:** Your question has major subheadings. One concerns how nerve impulses are transported along nerve fibers, or axons. There is a certain electric potential—about a tenth of a volt—across the membrane of the axon of a nerve at rest. But when some stimulus reaches the beginning of the axon, ion channels in the membrane there open briefly, positive ions flow into the axon, and the membrane potential changes. The potential change at the next region along the axon is somewhat less, but if it is still great enough to cause ion channels there to open, it is augmented by another influx of positive ions. Because of that positive feedback, the change in potential travels unattenuated along the length of the axon. The impulse travels along the axon like the snap of a rope at one end travels to the other end. Information, rather than anything physical, is conducted. But the transport is ionic in the sense that it involves the flow of ions rather than electrons.

When the impulse gets to the specialized structures, the terminals, at the end of the axon, the change in potential there causes release of a substance called a neurotransmitter. The transmitter diffuses to the next nerve and, by changing its permeability to ions, makes that nerve either more or less likely to fire. Between twenty-five and fifty neurotransmitters are known, although as short a time ago as about twelve years only four were known. New ones are being discovered every year. All the known neurotransmitters are very small molecules. Many, like gamma-aminobutyric acid, are amino acids. The enzyme acetylcholine and the hormones epinephrine, or adrenaline, and norepinephrine are among the most common. Why so many neurotransmitters exist is not known.
**Audience:** But if the transport of a nerve impulse is ionic, how can the impulse travel so fast?
**Hubel:** The speed of transmission, which ranges from about 1 meter per second to about 100 meters per second depending on the type of axon, is entirely predictable from such factors as the capacitance across the axon membrane and the permeability of the membrane to ions. You apply an equation not much more sophisticated than Ohm's law and out comes the transmission speed. One of the reasons nerve impulses travel so fast is the fact that axons are encased, everywhere except at particular points called nodes of Ranvier, in an insulating sheath of myelin. The flow of ions through the membrane occurs almost exclusively at those nodes, which are about a millimeter apart.
**Audience:** Is the same mechanism involved in the transport of audio signals?
**Hubel:** There are no basic differences

between the transport of auditory and **visual signals,** Each nerve system has some very specialized cells, but essentially the same transport mechanism is involved.

**Bitensky:** Are the neurotransmitters small so they can diffuse rapidly, and does their variety support subtle dialogues among nerves?

**Hubel:** Well, yes to the first question. The smallness of the molecules probably reflects an evolutionary drive for faster diffusion and easier release and uptake. Concerning the second question, the terminals of certain axons contain many different transmitters, so the opportunity for a much more complex dialogue exists. But I don‘t know of any cases in which more than two are released. Usually one is a so-called modulator, and the other is really doing the job, The modulator may change certain things, but in fact usually it is not known why more than one is released. It can be shown that one is enough to do the job.

**Bitensky:** Do neurons react to a variety of transmitters?

**Hubel:** Usually to at least two-one excitatory and one inhibitory.

**Audience:** My question is addressed to anyone who wishes to respond. In view of the complexities of the human nervous system, do you think computer-based artificial intelligence makes any sense?

**Hubel:** That is something I think about a lot because I have quite a bit of dialogue with a number of friends who work on artificial intelligence. I think that [he majority of people in artificial intelligence are not trying to produce a thinking brain, or anything like one, but to build intelligent machines for image translation, robotics, and so on. Those are very worthwhile goals, so one can’t object to them any more than one can object to the goals of, say, electronic engineers. On the other hand, a certain number of people in artificial intelligence are trying to learn how the brain works by developing computer programs to solve problems the brain is known to have to solve. They then ask whether the brain solves the problem the same way. Their efforts are very useful because the more people who are thinking about how the brain might work. the more guidance we have as to the type of experiments that we might do. I'm not sure whether that is the answer you want.

*David H. Hubel*

**Bitensky:** The differences between brain and computer arc very striking. The brain is terribly slow compared with the computer, but the richness of its interconnections- about $10^{15}$ synapses-is far, far greater. Many scientists in artificial intelligence say vehemently that it is just as absurd to try to emulate the brain as it is to try to fly like a bird. Fixed-wing airplanes are quite different from birds. Certainly. many fascinating things may emerge from understanding how the brain solves various problems.

**Audience:** Would any of the panel care to comment on whether extrasensory perception-ESP-is an unsolved problem in the science of life?

**Drake:** I’ll be glad to answer that one. About once a week 1 get a letter from someone who tells me I am wasting my time because he or she is already in contact with the extraterrestrials through ESP. My response is always to ask the person to tell me something the extraterrestrials know that we don’t know already. So far I've gotten no response. Adding to my skepticism is the large number of experiments conducted daily that very conclusively refute ESP. Those experiments take place primarily in two places—Reno and Las Vegas. The odds of winning some of the games of chance played there, say blackjack or roulette, are about I percent lower than the odds of losing. So if even a very few people had enough ESP to foresee or influence what is going to happen even 1 percent of the time, they could become regular winners and run the casinos out of business. The entire gambling industry would collapse. As far as I’m concerned, the fact that the casinos continue raking in the money day by day proves conslusively that ESP does not exist.

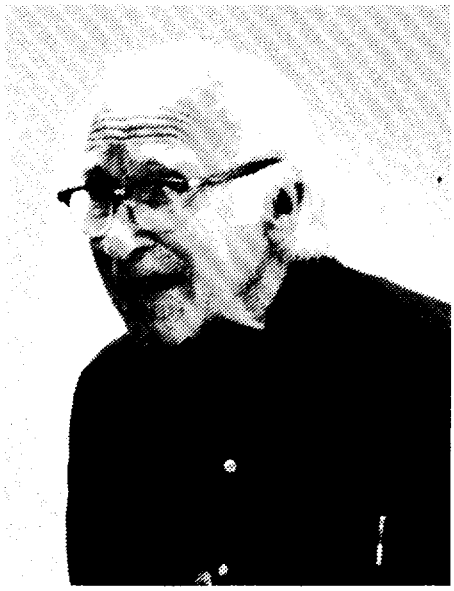
**Audience:** My question is addressed to George Wald. Although Wilder Penfield may have been unable to locate mind as a thing in the cerebral cortex, he very definitely showed that mind as a process is located in specific hard-wired structures in the brain. So can’t we say the the mind is located totally in the cerebral cortex and in the reticular formation?

**Wald:** I can only comment. I spend a great deal of time trying to sort out the obviously sloppy ways in which the words mind and consciousness are used. Yes, indeed, we can determine to a degree the pieces of machinery that are involved in the workings of the mind or consciousness. But where does that get us? Some great physicists have essentially said that all matter has an accompaniment of mind. What do they mean by that? They don’t mean

that stones are intelligent as we understand intelligence, still less that stones are self-aware as we experience self-awareness. Let me try to explain what they mean. A former professor of physiology at Harvard Medical School, Walter Cannon—whom 1 remember as a very wise person—wrote a book called *The Wisdom of the Body.* What did he talk about in that book? Well, he talked about the very fine regulation of the concentration of glucose in the blood, of body temperature, of the pH of body fluids, and so on. As the great physiologist Claude Bernard said, the constancy of the internal environment is the condition of a free life. We can go to the Arctic or the tropics, and we are free because of all that internal regulation. But please note that the regulation is unconscious. It has nothing to do with will or intelligence, In fact, one can only interfere with the regulation by intruding with one's intelligence. The English scientist Galton tried for one day not to draw a breath without willing it. At some point he decided he'd had enough of the willing and then was deeply embarrassed to find that his breathing stopped. If he hadn't somehow gotten through that phase, he would have probably passed out, and the unconscious regulation would have taken over again.

Now in exactly the sense that one can speak of the wisdom of the body, one can speak of the wisdom of the planet, of the solar system, of the universe. But it is *wisdom,* not intelligence, and wisdom in the sense of fitting together. 1 may have seemed yesterday to be disparaging silicon when I said, "And that's why silicon is good for making rocks, but to make living organisms, we need carbon." But if silicon weren't good for making rocks, we wouldn't be here. Rocks are the skeletons of the planets—so thank heavens for rocks. Things fit to a remarkable degree.

Mind or consciousness are involved



*George Wald*

in a tremendous range of human activities. At one end is the child learning to avoid the fire. An awful lot of learning is just personal housekeeping. At the other end is mathematics. Tell me where mathematics comes from and wherein lies the rightness of mathematical thinking. One might think first of its self-consistency, but Godel poked holes in that. I lived next door to a mathematician for a while-and I mean a creative mathematician, one who makes mathematics, not just uses it—and 1 never saw that man working. He spent his mornings in the bathtub and his afternoons quietly walking up and down the street with his little children. But he was a fine mathematician. Eugene Wigner wrote a nice essay asking how it is that mathematics fits physics so well. He concludes that it is simply a miracle, one for which we should be grateful.

I want to mention what Schrodinger, no mean physicist, says in the last chapter of his book *What Is Life?.* He says that he has been interested in Eastern philosophy for many years, and then he asks whether we are perhaps mistaken in thinking that there are as many minds as there are bodies. Clearly there are many bodies, but perhaps there are many fewer minds, perhaps only one. I do not believe in ESP, but I do think that the experiments done to determine whether ESP exists are laughable. They are like trying to produce a physical explanation for the existence of God. But the idea of one mind has something in it.

Let me say one more thing. The Judeo-Christian god *made* the universe; the Hindu supreme god Brahman *thinks* the universe. Is it possible to think reality? Theoretical physicists seem to do it. It started when Paul Dirac saw that his wave equation for the electron was satisfied by another particle of opposite electric charge, and then that particle—the positron—was discovered the next year. Now it is pretty much taken for granted that if a theory describing some known aspect of reality has alternative solutions, those solutions also have physical reality.

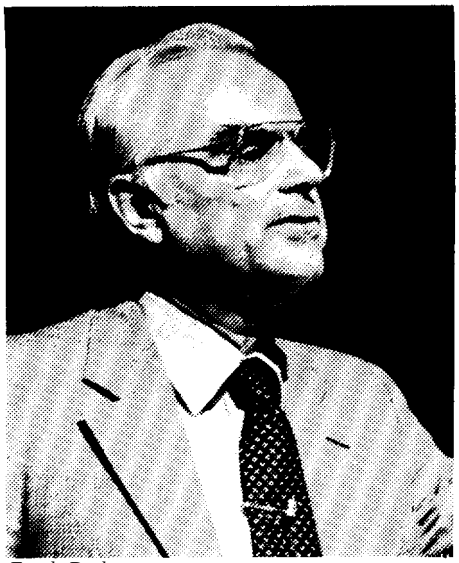
**Hubel:** I would like to respond to the original question. We humans tend to make up words that have perfectly good uses—the word sky is a good example—and then try to reify those words, to identify them with physical things. The mind can no more be regarded as a thing located some particular place than the sky can. But astronomers don't study "the sky" or "the heavens" or worry about where "the sky" is, They study all that we know constitutes "the sky". Some day we may regard the mind and consciousness the same way.

My hang-up with what George talked about yesterday has to do with what makes biology profoundly different from physics and the other natural sciences, namely evolution. In terms of evolution, the mechanisms responsible for Cannon's wisdom of the body are very well understood right down to the molecular level. We have no indication that any such guiding force exists in, say, physics. I'm thankful that ice floats and that carbon atoms form

chains, and no one can say what a universe in which those facts didn't hold would be like. But I don't go along with invoking an all-permeating mind or consciousness to explain them. The very idea of a permeating force is a religious concept. It falls outside the realm of science. We have come a long way, thanks to scientists like Darwin, toward transcending the conflicts between science and religion. It is true that some scientists-Sherrington, Penfield, Eccles, and Schrodinger, for example-commit one part of their consciousness to science and hold in reserve some marginal part that is the source of soft statements. I find those statements disturbing because they tend to become identified as scientific statements although they are not. I'm not suggesting we should ignore everything outside science. I don't think *that* highly of science. But it a good game to be in. It's very interesting, so interesting that I find talk about ESP rather silly. There are enough things to say gee whiz about in real science that we don't need silly things like astrology to keep ourselves happy.

**Audience:** In the mid thirties von Neumann suggested that consciousness might play a very significant role in the interpretation of quantum theory, in the understanding of what measurement means. That idea was followed up by London and Bauer and is being pursued to this day by Eugene Wigner. It may be at the roots of one 01 the great physical theories of our time. I would like Professor Wald to comment on what he feels the role of consciousness might be in future theories of matter.

**Wald:** First I want to respond to what David said. I am a scientist, and very glad to be one. In fact, I have spent my life pretty much as a strict constructionist in science. I certainly think that evolution is a great thing and that the wisdom of the body is understood. Perhaps natural selection. was involved in the evolution of a universe in which ice floats and carbon atoms form chains. Also I believe that every thoughtful scientist realizes that science deals only with a marginal part of reality. Reality is the very big picture, and science can deal cleanly and quantitatively with



*Frank Drake*

only a portion of that reality. Science cannot deal with what are in many ways the most important aspects of our lives. A Harvard great, the mathematician George Birkhoff—do you know what a Harvard great is? A Harvard professor who is still there so he can tell you he is great— wrote a book called *Aesthetic Measure*. In it he presented a formula by which one could quantitatively assess the aesthetic value of a work of art, such as Beethoven's Ninth Symphony or Rembrandt's *Self-Portrait.*. Then he decided to write a sonnet that would rate 100, and he did. It was a lousy sonnet. That is what the computer might do—write lousy sonnets.

**Hubel:** George, I think you are misconstruing what I said. I would be the first to agree that science plays a marginal role in our lives and has little if any immediate relationship to the most important things we do and say. I was expressing a negative opinion about scientists who include, as a last chapter in a supposedly scientific work, their wooly, nonscientific, difficult to understand thoughts about, say, mind and consciousness.

**Wald:** I don't share your negative feelings. Science is a path, one among many. It is the path to the boundaries of what we know. Of the many paths I prefer that of science to all others, perhaps because it does have boundaries. You seem to be saying that scientists shouldn't look beyond the boundaries, and if they do they should keep their wooly thoughts to themselves. Many scientists have looked beyond the boundaries-Newton, Maxwell, and so on down the line. How does one hate the temerity to speak with superiority of such people? I'll admit, though, that wc played that game as graduate students, saying too bad about that last chapter of Jeans', too bad about that last chapter of Eddington's.

**Bitensky:** It's time to move the discussion forward. I believe that David was not telling scientists to stay within the boundaries. He was saying that what lies beyond is simply not science. Now I would like Jack Sepkoski to comment

*J. John Sepkoski, Jr.*

on how human consciousness might affect the speciation and extinction that characterize evolution on the earth.

**Sepkoski:** First I want to emphasize that my comments yesterday about the constructive aspects of extinction-constructive, that is. on a time scale of several tens of millions of years-were not meant to lend support to a so-what attitude toward the effects of human activities on the biosphere. After all, we have no way of knowing whether those effects will. in the long term. be constructive or destructive, and what may be constructive to the entire system in the long term may be very destructive to individual species, even ourselves. in the short term. But it is fairly clear that massive re-engineering of the earth is causing a departure from Darwinian evolution, and genetic engineering can only bring about an even greater departure.

I should like to comment that I am less amazed by the existence of life than Professor Wald is, perhaps because of the rashness of my relative youth. Also I don't view intelligence as the pinnacle of creation, as being pre-eminent in and of itself. Intelligence is only one solution to survival, one that has been tried by a variety of organisms. Some organisms, the social insects, for example. rely on collective rather than individual intelligeoce. But survival of a species can be promoted by any number of tricks—by being camouflaged or showy, by being able to run fast, to reproduce quickly, to climb trees. That is why we enjoy such a rich variety of fauna and flora. But human intelligencc coupled with culture is a factor very different in kind from those at work in evolution until the last few centuries. and the biosphere faces a whole new ball game. Before evolution had no purpose: it produced what could survive, not what should survive. Now the biosphere is increasingly subject to human purposes, to the uses we make of the

*Mark W. Bitensky*

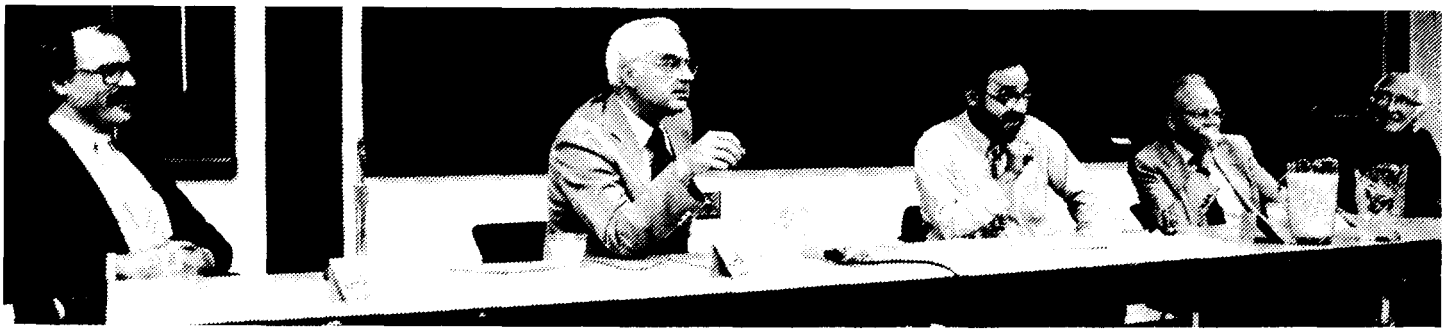
earth. Thus, the history of' the earth, which extends back some four and a half billion years, has moved into a very different era.

**Audience:** May I ask Dr. Drake what will be the next step after signals from an extraterrestrial civilization are detected?

**Drake:** That will depend on what we detect. What is most likely to be detected is a signal at a signal-to-noise level so low that no information can be extracted from the signal. So we will know only that another civilization exists. But of course that will be big news in itself. Then we must do whatever is required—build a much larger radiotelescope system, for example-to obtain information about that civilization. That information may have a great influence upon our own civilization. Or it may turn out that the extraterrestrials are so different from us that learning about them will be motivated only by scientific curiosity, like learning about the ecology of elephant seals.

**Audience:** Dr. Sepkoski, you implied yesterday that some maximum number of species exists at any given time, What might be the mechanisms for enforcing that maximum?

**Sepkoski:** The maximum is a relative, not an absolute, maximum. Probably some absolute maximum exists, since the earth can support only so much biomass and the efficiency of energy transfer can be only so great. But the number of species existing at any time has never been anywhere near the limit imposed by those factors. On the earth today we see local ecological systems. particularly islands, approaching an approximate equilibrium as new species appear and existing species vanish, The equilibrium number of species can increase or decrease, however, if a pool of species is introduced that uses the habitat and its resources in an entirely different way. That has been observed. for example, on oceanic islands and in a number of habitat islands on the continents. The fossil record over hundreds of millions of years for, say, the whole oceanic ecosystem presents a very similar picture. We see an approximately constant number of families and genera. We also see the equilibrium perturbed by several large mass extinctions and then quick rebounds to the former level, That level seems to be maintained by background extinction, or slow attrition, of existing species and slow replacement by other species. The slow attrition of species was probably caused by competition among organisms for limited resources as well as by perturbations or small "catastrophes" in local ecological communities; replacement resulted from normal processes of' speciation. We also see jumps in the steady-state number of taxa when a different style of fauna appears, for example, when Ordovician fauna replaced Cambrian fauna. And the animals that became dominant after the great Permian extinction did things in yet a different way. So it makes sense that the number of species in the oceans today is greater than it was 250 million years ago. We can imagine that if marine organisms found yet another way of organizing ecosystems, their number might jump even higher. We see terrestrial para-



lels, especially among plants—plateaus of diversity maintained by balanced speciation and extinction and jumps in diversity due to new ways of doing things, particularly at the advent of angiosperms. We have some hints of the same thing going on with vertebrates and perhaps with insects, but the insect fossil record is pretty messy.

**Audience:** I'd like Dr. Sepkoski to comment on Fred Hoyle's theory that life at some level pervades [he universe and that that cosmic life is the origin of life on the earth,

**Sepkoski:** I haven't thought very critically about Hoyle version of panspermia because I find it too easy to dismiss out of hand. Many ideas of that sort are based on the notions that 4.5 billion years is not enough time to produce the diversity of life we see on the earth today or that 1 billion years—the time between the birth of the earth and the age of the earliest fossil evidence of life—is not sufficient time to produce life itself. Unfortunately, we don't have theoretical principles of evolution with which we can quantitatively predict absolute rates of evolution. All we have right now is an ability to measure relative rates of evolution in some situations, My impression from looking at the fossil record, though, is that evolution can work extraordinarily fast when it is unconstrained. In the absence of competition and crowding, mutations and other accidents produce a huge array of variations from which natural selection can produce a wonderful array of outcomes. I don't believe we need panspermia or any other means of inoculating the earth with life, But that's only my gut reaction to what I see in the fossil record. and we do need quantitative theories before we can say definitively that such hypotheses are unnecessary,

**Bitensky:** When we speak about evolution. we are really talking about the evolution of DNA, and there is now a lot of evidence that the shuffling of whole exons is one of the changes that occur in DNA. That shuffling allows the mixing of very big pieces of DNA and so could be responsible for very rapid evolution.

**Sepkoski:** Exon shuffling certainly leads to rapid rates of change in DNA, but in fact speciation doesn't require any changes in DNA. The extraordinary genetic variations among individuals of a species is more than sufficient. Mutation could cease today, and after tens of hundreds of millions of years a far different biota would inhabit the earth.

**Bitensky:** But the extraordinary variation is. in retrospect, a reflection of the plasticity and heterogeneity of DNA. which is made possible by shuffling.

**Audience:** My question has several parts and is addressed to Professor Sepkoski and Professor Drake. First, what mechanism is behind the rapid increase in number of taxa after a mass extinction? Second, is there some mechanism that prevents the simultaneous existence of more than one intelligent species? And finally. wouldn't it be very depressing for us humans to come into contact with a civilization much more advanced than ours?

**Sepkoski:** In answer to your first question, we see rapid evolution following mass extinctions because of a change not in the process but in the boundary conditions. Variations occur all the time. but most of the variations don't survive. Most new species probably arise from small. local, slightly variant populations of existing species. But ecologists have learned that such local populations disappear at phenomenal rates, probably because of competitive pressures that keep them small in size and hence susceptible to extinction. But if somehow the lid of competition is lifted so that populations can expand, then the probability of their extinction goes way down. And then we see rapid increases in number of species.

Turning next to the question about a possible limit on the number of intelligent species, first we need to define intelligence. I prefer an operational definition. as a measure of the ability to control, to re-engineer, the local environment in a nonstereotyped way. I mentioned before that a variety of animals can re-engineer habitat, and they are not all even mammals. I think that competition is inevitable if more than one intelligent species exists, and in that competition only one will win, will become pre-eminent. Now I yield to Frank.

**Drake:** Why is there only one intel-

ligent species on the earth? Because of the greed and selfishness of *Homo sapiens.* The fossil record indicates that at some times more than one intelligent species inhabited the earth simultaneously—Neanderthal man and Cro-Magnon man, for example. The fossil skulls of those other species often show signs of having been hit with a blunt instrument, and one suspects that it was *Homo sapiens* who was wielding the blunt instrument, getting rid of all competitors.

The graph of number of species versus brain weight-corrected for body weight—is very interesting. For aquatic creatures, particularly aquatic mammals, the curve is continuous. There are species with brains almost the size of those of the dolphins and killer whales, which have the largest brains. But the curve for terrestrial mammals is continuous only up to a certain brain size, then a gap occurs, and beyond that gap there is only one *species—Homo) sapiens.* What created that gap? We did. We eliminated the competition to have the earth to ourselves, That is our nature, and not something to be very proud of. The dolphins and the killer whales have not done the same thing. Terrestrial mammals seem prone to population explosions. and the resulting population pressure leads to fierce competition. But marine mammals do not engage in population explosions, The populations of dolphins and killer whales could expand enormously, since they have very few predators, but for unknown reasons that doesn't happen. So those most intelligent marine mammals have no drive to eliminate near rivals.

In any case one intelligent species dominates the terrestrial ecosystem on the earth. What can be said about the universe? If the other intelligent creatures out there are like us, then they will want to eliminate near competitors. So when they see a new intelligent species emerging, they will stamp it out just as

we stamped out the australopithecines. However, the extreme expense of interstellar travel may be our salvation, since no possible benefit could justify the cost. On the earth inferior cultures have been exploited by superior cultures, as. for example, the Europeans exploited North America and Polynesia. But getting to North America and Polynesia was easy. Going to a distant solar system for self-protection or economic reasons would cost far more than any possible benefit. So the great distances between stars and the laws of physics create a very effective and beneficial quarantine. Intelligent civilizations that far apart can neither exploit nor attack each other. We hope. But they can help each other by communicating.

**Audience:** Today's feats of technology would have been regarded as impossible only a few hundred years ago. So isn't it rash to say that physical contact with other intelligent life is unlikely'? Maybe traveling faster than the speed of light *is* somehow possible, for example.

**Drake:** Yes, we certainly should not neglect the possibility that all the physics relevant to this problem is not known. History raises big red warning flags about thinking that we know everything.

Regarding the question about our egos being demolished by contacting a civilization more advanced than ours—and that is the most likely possibility—I don't consider that a problem. We all have been exposed to minds and accomplishments greater than ours. In fact, for most of us that is a continual experience. But the result is more often inspiration rather than depression. I don't believe the human brain is limited in any fundamental way and think it can emulate the power of any intelligence we may find in the universe.

**Wald:** We humans have stockpiled all the hardware necessary for destruction of our civilization. although at the moment it has not been used. How likely is it that other civilizations have committed suicide with similar hardware and that no one is out there for us to communicate with?

**Drake:** It has been said that the civilizations we detect will be those that have passed successfully through the nuclear crisis, which will occur in every civilization almost simultaneously with the development of the technology necessary for communication with other civilizations.

**Bitensky:** Perhaps intelligent extraterrestrial beings are waiting to communicate with us until we prove our worthiness by transcending the nuclear crisis.

**Wald:** The supposition on the part of many people is that the civilizations we might contact would be benign. Is our civilization benign? We grow viruses in our closest mammalian relatives, we slaughter bottle-nosed dolphins by the millions, and we are far from benign even to our fellow humans. It seems to me that we have more to worry about than simply having our egos crushed.

**Hubel:** What do anthropologists have to say about greed being the cause of extinction of the predecessors of *Homo*

*sapiens?* Would greed have been as powerful a force in the early stages of' our evolution?

**Sepkoski:** Greed may be another word for competition, which has been proposed to explain the disappearance of Neanderthals and certain other hominids. Neanderthals had larger brains than *Homo sapiens* does, and a lot of Neanderthal genes may still exist in Europe. A Neanderthal could walk down the street today and cause no comment. The australopithecenes disappeared in Africa about the time *Homo habilis* started to become common. Perhaps their disappearance was due to competition between the two, but perhaps it was due to some change in the ecology.

**Audience:** Why are we looking for signals originating someplace out there when there are reports of signals from extraterrestrial beings right here'?

**Drake:** I assume you are referring to UFOs. The evidence for UFO sightings that have been studied in detail simply falls apart. Of course, not all the reports have been studied in detail. but those that have can be attributed to natural phenomena or to hoaxes. It would be nice if the intelligent beings came to us—it would make life simple—but I see no evidence that they have.

Let me comment on our failure so far to detect other intelligent life in the universe. The silence we have heard is not in any way significant. We simply have not looked long enough and hard enough, have not explored a large enough chunk of the cosmic haystack. We can speculate that they are watching us to see if we are worth talking to, but an even more likely speculation is the existence of an ethic that says there is no free lunch in the galaxy. If we want to join the community of advanced civilizations, we should have to work as hard as they do. So they would send a signal that can be detected only if we put as tnuch effort into receiving as the

do into transmission. They are not go ing to serve up wondrous things on a silver platter to a new civilization. We must earn access to their information.

**Audience:** What is the opinion of the panel about research at reputable institutions in areas beyond the boundaries of pragmatic science, for example, at Princeton on engineering anomalies and at Duke on paranormal phenomena?

**Wald:** I know the people at Princeton, and I like them very much. They are serious and well intentioned, but I am not familiar with the data on the anomalies they are investigating [see *Margins of Reality: The Role of Consciousness in the Physical World* by Robert G. Jahn and Brenda J. Dunne, Harcourt Brace Jovanovich, Inc., 1987]. What most interests me is the very concept of a system of communication that we don't have to pay the telephone company for—a universal mind or a collective mentality. I think that the attempts to study such means of communication are too mechanical, though. What goes on in a good mathematician's head is closer to the answer, and that isn't going to start or stop machinery.

**Hubel:** People, especially people with little scientific education. can come up with some pretty silly explanations for natural phenomena. But I feel that trying to disprove such explanations is not a sensible strategy. Let them die of attrition as facts accumulate. That usually works, and it certainly saves time and money. I think Duke's venture into the paranormal brought it great discredit scientifically. As for astrology and fly - ing saucers and such, I put them under the heading of things I wouldn't believe even if they were true.

**Drake:** I want to add a comment here. Most people don't understand statistics and probability, and they don't recognize that although an event may be very

improbable, it does eventually happen if enough opportunities for it to happen exist. So the fact that a friend calls you on the telephone at the exact instant you are thinking about the friend is not evidence for telepathic communication, And I repeat that many experiments refute the idea. We certainly don't see any evidence for telepathic communication between bridge partners, for example. By the way, the ESP project is now disassociated from Duke.

**Audience:** Dr. Drake, you said yesterday that the rate of generation per galaxy of planets with intelligent life was about one per year. Did you include in your derivation of that rate the possibility that large mass extinctions may be necessary for evolution of intelligent life?
**Drake:** No, I didn't include that factor, which is rather speculative. But if mass extinctions are somehow involved in evolution of intelligence, we have no reason to believe that the processes that cause them on the earth would not also be operative out there. Clouds of comets, for example, should be present in solar systems other than our own. The rates of mass extinctions would undoubtedly vary from place to place, but that would not significantly change the rate of generation of civilizations.

**Bitensky:** Despite the richnesss of our discussion, I must point out that we can continue it only a little longer.

**Audience:** My question is addressed to Dr. Sepkoski. How significant is the difference between the periodicity of extinctions and that of magnetic reversals or of the comet impacts predicted by the Nemesis scenario?
**Sepkoski:** The difference is real—greater than the uncertainties in the data.
**Audience:** Then what is the cause of the extinctions?
**Sepkoski:** I don't know. Impacts are certainly involved in some cases, and so are climatic changes. Maybe the thing to do at this point is to throw in all the data that might be relevant and carry out a huge analysis of variance.
**Bitensky:** Are you willing to entertain a multiplicity of causes of extinctions'?
**Sepkoski:** Yes. The nonperiodic mass extinction of large mammals that occurred about 10,000 years ago is clear evidence for a multiplicity of causes.

**Audience:** I believe Einstein is credited with saying that imagination is more important than knowledge. Would any of the panel care to comment on the process of imagination or the enhancement of that process?
**Wald:** The degree to which we program our children is fantastic. A child is a wonderful thing, and it lives in the whole universe. It does everything—it dances. it sings, it paints pictures, it makes objects. Then comes the point, in our culture at the age of eight or so, at which the family, the school, the whole of society say to a child that it is time to stop playing and to learn how to work. The child is put on a track and brainwashed with questions like "Why sing? You aren't going to be a singer, are you?" and "Why paint a picture? You aren't going to be an artist. are you?" Putting a child on a track is satisfying because it implies the child is going somewhere—there are stations and a schedule. But the track prevents the child from going anywhere else. Einstein and Bohr, the greatest persons I have ever known, were also the most childlike in the sense of being eager to explore just everything. Something terribly traumatic has happened to all of us, as evidenced by our lack of memory of early childhood. Very few of us can remember much more than occasional snapshots of our lives before school age. At a conference in India on consciousness, the first I was ever exposed to, there was much talk about superconsciousness, the idea of using more than what is said to be a small fraction of our brains, and about reforming education to foster superconsciousness. When my turn came to speak, I said that I thought what they were reaching for lay not ahead of them but behind them—in their childhoods. ❑

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