within a specific context or type of activity. And, since I was referring in my discussion primarily to the scientific enterprise, the criticism of conscience would be directed to that partial functioning of the self. We should not, however, lose sight of the more "wholistic"—the figure of part and whole has unavoidable limitations—sort of judgment we can make upon ourselves as illustrated by St. Paul's well-known confession: "The good that I would, I do not, and that that I would not, that I do." This judgment is applicable in *any* context and thus refers to the self in a more basic dimension than that represented by any partial activity.

What seems to me of the greatest importance is that we are becoming increasingly aware of the important connections between spheres of learning and dimensions of experience long separated by vested interest, prejudice, or lack of vision. Therefore I am grateful to Dr. Tannous for carrying the discussion forward.

"Where is everybody?"

To the Editors:

I would like (at the risk of sounding a bit pedantic) to add some thoughts to the stimulating and often amusing article by John A. Ball, "Extraterrestrial Intelligence: Where Is Everybody?" (*Am. Sci.* 68:656–63, November 1980). While I agree with Dr. Ball that no other place in the solar system seems to be suitable for life to originate, the phrase "life as we understand it" should perhaps be added to cover all potentialities. We are, after all, defining "life" from the very human and exclusive viewpoint: other life-forms may exist but we, as humans, simply do not have the abilities to detect them.

In considering the evolution of civilization, it would indeed be difficult to predict developmental states for those older by "eons," but this, of course, assumes that the present age of our universe is in excess of 15–20 billion years. Otherwise, again assuming that life began on planet Earth 3–4 billion years ago (because approximately 10–15 billion years would have been required before conditions would become favorable), we might have to assume further that life in other systems required the same predevelopmental time, or that evolution of star systems otherwise proceeded at a different rate throughout a given galaxy or universe.

Holding to the former assumption precludes eons-old civilizations; holding to the latter implies that the origin of life (again as we define it) is not, and never will be, a unique event. If life evolved early (eons-old civilizations) and intermediately (Earth), then it lies entirely within the realm of possibility that life could evolve at a still later date somewhere else in the universe. The thought is intriguing that someday, at some future spacetime, we will be the advanced civilization, not the primitive form. It may restore a bit of confidence in our previously blasted egos.

In regard to wrong information and lethal genes, can it not be asked whether wrong information is information anyway? If it is wrong, presumably a value judgment will have to be made, so the assumption is that all nonredundant information does indeed become equally useful or valuable. After all, the fact that a gene is shown to be lethal, is, of itself, an informational bit. Existence of lethal genes fits very well into the theory of natural selection and the concept of adaptation. Had mankind, for example, not found a way to sustain hemophiliacs, this particular gene might well be on the way out of our human genetic pool.

As to the generalization that mankind descended (ascended?) from Cambrian worms, as did modern worms, and allowing for artistic or poetic license, we need not necessarily ask "What happened?" Some worms may indeed have "stagnated" (a word rife with teleological anthropomorphism), but others *evolved* either from the stagnating ancestors or from other lineages, and some worms went extinct. But stagnation is not necessarily indicative of primitive state, nor is stagnation necessarily bad. Some very important stagnant species include horseshoe crabs, cockroaches, and ferns. And, to be sure, *some* people are more interesting than worms, but I have known some worms with whom I would much prefer to be acquainted rather than with *some* people, speaking comparatively.

And, by way of *reductio ad absurdum,* I am reminded of a cartoon I saw several years back wherein a little green man with a tricolor eye in the middle of his forehead is saying to a traffic light: "Take me to your lead-

er." If we are forced to interact with very advanced civilizations, then perhaps we would proceed along the lines of several civilizations here on Earth when they first met the white man as whaler, missionary, or pioneer. We might simply trade away all of our valuables, our ethics, and our religious and socioeconomic history for colored beads, venereal diseases, and intergalactic firewater.

I would agree that universal biological laws must include those of mutation and natural selection, and perhaps even sexual reproduction (although a case can be made against it by referring to parthenogenetic species, or processes of budding or division in some earthly forms), as well as speciation. I am not convinced that ecosystems in other parts of the universe need function, however, as do those on Earth. In a utopian environment, for example, competition, territoriality, and aggression may not be required. After all, if a species has everything it needs to exist and to reproduce, then it need not compete. Whether the species would ever advance in an evolutionary sense is, of course, another matter.

I would question whether genetic engineering as used in this context can be considered a form of evolution. By engineering the genome are we not, in fact, sidestepping evolution? Evolution does not proceed toward an end or a goal; rather it proceeds with the survivors adapting to the environment of the time. Genetic engineering, on the other hand, is by and of itself goal-directed. We produce survivors preadapted to survive in whatever environment (Earth, moon, planets, etc.) we seek to occupy, as a goal.

The point is very well made, however, that numerous biological niches will be found unoccupied in space. The million-dollar question is whether man, or a man-machine, will be able to occupy any of them. One can envision a population explosion similar to that seen in English sparrows, starlings, Japanese beetles, and Australian rabbits, should man find a beneficent and unoccupied niche. Will an advanced civilization use methods to control this outbreak of pesky humankind? And if so, could we humans by means of genetic engineering come up with a resistant android or humanoid each and every time an "anthropocide" is employed? The idea is not new, of course, having been utilized in several science-fiction stories in the late 50s and 60s.

The points I am making here should not be misconstrued. I am not taking issue with any part of the article; indeed, I thoroughly enjoyed it and was left with some rather profound points to ponder. It may well be that much of what we do or consider to be important in searching for ETI will ultimately prove to be without basis, but it is nevertheless intriguing. Perhaps the entire concept can be summed up as not "Where is everybody?" but rather "Is there anybody?"

Robert H. Gore
Smithsonian Institution
Fort Pierce Bureau
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To the Editors:

Dr. Ball has developed several interesting hypotheses in answer to his provocative question about extraterrestrial intelligence. I agree that the most fruitful question we can ask about ETI is "Why are we unaware of any?" I would like to offer an additional hypothesis, which Ball seems to have overlooked or unjustly eliminated in his preliminary assumptions.

Ball's five possible answers all result from the assumption of continuous development, and this implies control over an essentially unlimited free energy source (such as controlled thermonuclear fusion). But what if this mythical unlimited free energy source does not, in fact, exist? What if all "Earthlike" planets are subject to Earthlike resource constraints and all proposed unlimited energy sources turn out to be net energy sinks? Our lack of awareness of ETI may thus be evidence that free energy limitations are in force everywhere in the galaxy. While we are not alone, everyone else is in the same boat and not much more technologically advanced than we (even if they started sooner).

This argument is equivalent to Dr. Ball's "finite lifetime" or "stagnation" scenarios ultimately taking effect everywhere, with peaks or plateaus at or near the same level. While it is certainly true that "civilizations advance to the extent that they accumulate new information and knowledge and stagnate or regress to the extent that they fail to," they cannot

accumulate new information without expending copious amounts of free energy (unless they invoke Maxwell's demon—perhaps this time disguised as R2D2). Thus Ball's attempt to evade the free-energy implications of continuous development by assuming energy use and level of development to be unrelated is thermodynamically and economically untenable. If fusion or some other technology really *is* capable of producing unlimited free energy on an Earthlike planet, then Ball's hypotheses 4 and 5 might still provide the explanation for our loneliness.

But if net energy from fusion or other "unlimited" sources is not possible (and here I mean energy output greater than the total energy cost of all inputs, including constructing the reactor, running it, and paying all environmental costs), then it is not surprising that we have not heard from anyone. Their space programs must have shut down long ago for wasting energy as they turned all their efforts inward toward maintenance.

The question of the potential net energy yield of fusion (or other proposed "unlimited" energy sources) is of enormous importance to intraterrestrial intelligence since we are talking about some very expensive technologies. As J. F. Clarke has stated in a recent issue of *Science* (210:967–72): "Failure to develop a viable fusion reactor would be a tragedy, but early knowledge that it is indeed a false dream would prevent the waste of scarce energy development resources and technical expertise in a more drawn-out effort."

Are extraterrestrials providing us with important information on free energy limitations (that could save billions of terrestrial dollars) through their silence? The evidence is hardly conclusive, but I think this possibility deserves at least equal billing.

Torn and battered?

Sending *American Scientist* unprotected through the mails means that, inevitably, some copies reach their destination torn and battered. If your copy arrives in damaged condition, we will immediately send a new, *wrapped* copy on request. Wrapping the magazines separately in the general mailing would increase distribution costs appreciably; replacing individual damaged copies appears to be the best policy for the present.

Robert Costanza
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To the Editors:

My viewpoint on the interesting questions raised in John A. Ball's article belongs in category 1 of his list of possible answers. I think that Von Hoerner's presumption that "nothing is unique and most probably we are about average" is contrary to the evidence. In the terrestrial biosphere it is more nearly true that *everything* is unique, and surely we are far from average. There are many lesser terrestrial intelligences, but none approaching ours. Why?

There may well exist many extraterrestrial biospheres, but that they collectively, let alone individually, necessarily give rise to organisms at or above the level of human intelligence seems to me a second-order speculation for which a correct interpretation of the evolution of the terrestrial biosphere offers no support, as I suggested in a recent article in *Annals of*

Otology, Rhinology and Laryngology (87:5, Sept. 1978).

Human intelligence is a very recent development, the culmination of a long series of fortuitous interplays between virtually fortuitous features of the environment and virtually fortuitous variations in genomes and survival machines (to use Dawkins's term). The order of improbability of any given individual terrestrial interplay is astronomical, perhaps as large as that of the number of planets in the universe. Nothing in the inferred terrestrial series up to, say, the Pliocene enables us to predict the necessary emergence of humanlike intelligence. That it emerged here does not mean it could ever happen again here or that it is likely to happen in extraterrestrial biospheres.

B. Raymond Fink
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University of Washington
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To the Editors:

I am sure most readers of Dr. Ball's article were struck, as I was, with the almost axiomatic elucidation of the scientific complexities for the existence of ETI. However, I find it impossible to agree with the loss of over 100,000 bits of information in the terrestrial ecosystem during the period from 1.9 to 1.7 Gyr (B.P.) as shown in Figure 1.

Paul A. Wieselmann
Kaman Sciences Corporation
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To the Editors:

In addition to the manifold difficulties involved in detecting—and in being detected by—ETI listed by Ball, an even more fundamental and formidable obstacle to meaningful intercourse is the horrendous distance between us and even the closest stars. There are only about twenty stars less than twelve light-years removed from us. We are therefore confronted with time lapses of at least decades and, more probably, centuries between the emission of a signal and the earliest possible receipt of acknowledgment of its arrival.

There has thus been barely enough time for "eavesdroppers" to notice our signals, let alone tell us about it, and any attempt at interstellar communication is likely to tax the patience and stamina of prospective investigators as severely as it will challenge their longevity.

Carel J. van Oss
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To the Editors:

Let me suggest a minor variant to Dr. Ball's interpretation which I call the "silence-is-golden" hypothesis but which some may consider a paranoid view. Suppose that any given ETI, following Dr. Ball's reasoning, infers that many other ETIs probably exist and that they represent a broad spectrum of stages in technological development, creatures with whom communication might, in principle, be possible. What is this ETI's next reasonable step? I suspect that any careful risk/benefit analysis, incorporating guesses about the conceivable consequences, would lead to a "shut-up-and-listen" strategy.

No one should quarrel with trying to receive or intercept messages from other civilizations, but if human history offers any guide, it would be foolhardy to send out messages in search of those strangers based on the assumption that all listeners would respond benevolently. I share Dr. Ball's guess that the possible consequences would include being "engulfed and destroyed, assimilated or . . . annihilated."

On the contrary, since no ETI can be certain that it is number one, it would probably be wisest to restrict, as far as possible, any leakage of patterned energy that might reveal intelligent activity. So maybe all those ETIs are simply being prudent, waiting for someone else to break the silence—and maybe we should, too?

J. T. Enright
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University of California, San Diego

Dr. Ball replies:

I agree with many of Dr. Gore's points, but I think that his picture of

mankind trading away "all of our valuables, our ethics, and our religious and socioeconomic history for colored beads, venereal diseases, and intergalactic firewater" is further from the likely outcome than his equally vivid picture of "pesky humankind" trying to cope with occasional squirts of "anthropocide."

I suggest to Dr. Costanza that, just as hungry people, understandably obsessed with acquiring food, tend to exaggerate the importance of food and the difficulties of obtaining it, so with our current energy hunger we are obsessed with acquiring energy and we tend to exaggerate the difficulties of obtaining it. Like many other resources—food, wood, leather, iron, silicon, and so on—we do need some free energy, but there is a lot around. Our sun radiates some 3.8×10^{26} watts, about 4.5×10^{-10} or 1.7×10^{17} watts of which Earth intercepts, and most of that goes to waste. Mankind, if need be, can yoke this resource. I am suggesting, then, that even without hydrogen fusion or an equivalent energy source, we (and ETI) would still take off for the stars.

But fusion exists and we already know how to make it go bang! Our problem is to learn how to control it better. I don't know whether a tokamak or a stellarator will work, but if they don't, something else will—if not in this century, then next.

If I may paraphrase Dr. Costanza, he seems to say that unless we develop hydrogen fusion, neither we nor ETI will get into space. But we already have developed hydrogen fusion, and we already have gone into space.

The problem addressed by Dr. Fink is partly semantic. A thing can be unique, in that no other is just like it, and also average or ordinary, in that each of its properties lies near the median or mean rather than at an extreme of the distribution. I might say of a friend, for example, that he is just an ordinary Joe because he is average in height, weight, personality, intelligence, and so on; but he is also unique because no other man anywhere is just like him. I interpret the assumption of mediocrity to mean that the Earth's biosphere is average or ordinary, but also, I suppose, unique. Von Hoerner's wording of the original version of the assumption of mediocrity is perhaps unfortunate.

Dr. Fink may be right, of course, in arguing that intelligence is unlikely elsewhere, but intelligence is very adaptive. Once invented, intelligence allows its possessor to cope with environmental variations, even catastrophes, and to take over new environmental niches.

I am very impressed by the phenomena of convergent evolution. Eyes were invented thrice independently on Earth—by insects, molluscs, and fish. The latter two are remarkably similar, especially on superficial examination. Wings were invented at least thrice independently—by insects, reptiles that became birds, and mammals. The ability to learn, which is the basis of intelligence, was probably also invented several times independently. Rather than a dichotomy between mankind and other animals on Earth, I see an almost continuous spectrum of learning abilities, with mankind, indeed, at one end of the distribution.

The same sort of argument that Dr. Fink uses against the independent invention of intelligence can be used against the independent invention of eyes and wings. Mankind may be the result of a long chain of individually unlikely events, but if that chain hadn't occurred, then one of many other equally unlikely chains would have produced an equivalent result—intelligence. Given a niche for intelligence, someone, sooner or later, will invent it—if not mammals then maybe birds (crows are pretty smart) or even molluscs (so are octopi). Mankind is clearly ahead in the intelligence race (on Earth), but if we were to drop out or cease developing, someone else (dolphins?) might, in a million years or so, surpass us.

I apologize to Dr. Wieselmann and all *American Scientist*'s readers for what was just a slip of the pen in Figure 1.

To respond to Dr. van Oss, why wait until we invent radio? The scenario I visualize involves our sending probes to nearby stars in a search for extraterrestrial life—not necessarily intelligence; creepy crawlers would be wonderful! The probes would be similar to, but much more sophisticated than, the ones we sent to Mars. Having found life, we would decide whether to dabble or just observe. This project will take centuries and may last millennia.

Thus we (mankind) shall certainly start cataloging and studying ecosystems in the galaxy as soon as we are able; why should ETI do less?

Perhaps Dr. Enright's "shut-up-and-listen" strategy might be desirable, but I think it is impossible. The sun, the solar system, Earth, and mankind are all conspicuous; there is no way to hide. But I agree that there is also no point in deliberately waving our (red?) flag.

Science fiction contains such a plethora of ideas that one can find almost anything therein—good, indifferent, and bad: the problem is to sort it all out. Most imaginative scientists read at least a little science fiction, and some write it.

Erratum

In "Assessing the Risk of Exposure to Radioactivity," by D. J. Crawford and R. W. Leggett (*Am. Sci.* 68: 524–36, September 1980), the 1972 publication of the Advisory Committee on the Biological Effects of Ionizing Radiations, known as the BEIR I report, was incorrectly identified on page 535 and in reference 36 as the BEIR II report.