We are learning a great deal today about the way information is carried by living organisms. And the temptation becomes very strong to apply that information. Indeed, throughout the whole course of the history of technology, there has been a lot of application without much thought of long-term consequences.

We might better understand the application of this information in the perspective of the long and varied history of our own planet. We now know that about 4,560 million years ago—give or take a few million years—a series of chemical and physical processes took place which led to the formation of our planetary system, and we know that planets of various types were formed. We think we understand what those types are in relation to the medium from which they were formed and in relation to the composition of stars generally.

But perhaps the most important thing we have learned is that this process almost certainly has not been unique. We have had systems of bodies being formed for many billions of years. If these bodies happen to be large enough, they ignite and we have stars; and if they are not large enough to ignite, we have cold bodies; and if those bodies happen to be in the vicinity of a star, there will be planets.

We know that there are three types of such planets: planets which are small, very dense, and composed primarily of rocklike substances and metals—planets like Mercury, Venus, Earth, and Mars. Add to that a lot of ice and methane and ammonia, and you will have planets like Uranus and Neptune; and add to that a lot of hydrogen and helium, and you will have planets like Jupiter and Saturn, which can be looked upon as sort of embryo stars. If they had become larger, they would have ignited, and we would be living in a planetary system with two or three suns. Or perhaps more precisely, we wouldn't be living.

The more we look into the early geochemical history of the earth, the more it becomes apparent that life is not a miracle, but that life arose as a natural end-product of a sequence of chemical events. Life arose on a planet which had certain characteristics conducive to this origin—first, a medium in which complex chemical reactions could take place and second, a temperature which was neither too hot nor too cold. If it is too hot, the complex

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compounds simply are not stable. If it is too cold, chemical reaction rates are so slow that reactions don't take place.

Now we can ask the question: Given a planet that is not too large (like Jupiter which is really an embryo star); that is not too small (like Mercury or the Moon which cannot hold onto a liquid or a gaseous medium on which chemical reactions can take place); that is not too hot (like Mercury where complex compounds won't be stable); that is not too cold (like Uranus or Neptune) so that reaction rates won't be too slow: What is the probability that life will arise? The evidence indicates that the probability is very high.

THE UNFINISHED CHAPTER

by Harrison Brown

On earth there has been a beautiful sequence of developments starting with very primitive organisms, or with the first replicating molecule. Because all of them were exposed to ruthless selection effects and to dramatically changing environments throughout earth's history, certain developments took place. Perhaps one of the most important of the fairly recent ones was the oriented, controlled deposition of calcium, which enabled the existing organisms then to develop supporting and protective structures. This, in turn, combined with the emergence of the lung, enabled creatures to move onto the land. In sequence there appeared first amphibians, then reptiles, and then mammals. And finally, in a period which corresponds to but an instant of time, something brand new emerged which changed the entire course of evolutionary history. This was the emergence of what Julian Huxley called the power of conceptual thought—the ability to conceive of things, to solve problems, and to communicate with one's offspring in such a way that the whole process of learning becomes a cumulative process from one generation to the next. This power enabled man to invent weapons for hunting and fishing and tools for gathering food. Then it enabled him to invent perhaps the most important single cultural invention of man's long history—agriculture.

With this development, man quickly became the dominant animal on earth. It made it possible for a small percentage of the population to engage in occupations other than that of just gathering or growing food. It made it possible for the great ancient civilizations to

emerge. This happened less than 10,000 years ago.

With civilization's development, increasing levels of technological complexity evolved. This technological complexity, however, levelled off because it proceeded about as far as it could go within the existing framework.

Then not very long ago—indeed less than 300 years ago—we entered the Industrial Revolution, which has carried us since to an extremely high level of technological complexity—at least in the part of the world in which we live. And it raises a number of very important questions.

But when we look at the framework in which we live in the world, when we look at the problems that have been created as the result of our technology and the haphazard application of our discoveries, we can see very real dangers ahead. For one thing, we have seen a fantastic increase in our ability to destroy—in our military capability. We have seen weapons of fantastic power, thermonuclear weapons, come into the hands of first one nation, then two, three, four, and five. And there is no reason for us to suspect that it will stop.

A WORLD OF CONTRASTS

We can couple that with the fact that we are really living in an anarchical world in which there is no real law and order. And because we are living in a world in which technology has been applied in a very haphazard way, some people have become very rich, and others remain very poor. In the countries that have shared in the blessings of technology which produce an abundance of food and things, we seem to have gotten ourselves into what James Bonner refers to as a "positive feedback cycle" in which richness begets richness.

By contrast, those areas of the world—and this includes most people—where starvation is the rule rather than the exception, and where deprivation and misery prevail, find themselves in a negative feedback cycle in which poverty intensifies poverty. Indeed, the economic positions of these two groups are diverging very rapidly.

This raises a very real question. Can a high-energy civilization be stabilized? We don't know. It's the first time it's happened on earth. It might well be that it can't, but certainly we shouldn't stop trying. But it may well be that it can. This in turn raises another rather interesting question. If it is true that planets are abundant and that life is abundant in our universe, might it not also be true that the power of conceptual thought has arisen in many places within our universe and that many other high-energy civilizations may have arisen as well?

UNINTENTIONAL COMMUNICATION

It is clear that we are in a position to send out signals should we wish to. Indeed we are doing that unintentionally already. Frank Drake, the director of the Aerocibo Station radio telescope in Puerto Rico, pointed out some time ago that the world is reaching the point where an external observer could detect that something is going on here that could not be explained on the basis of natural processes. This is because of our large outpouring of microwaves in the form of television programs and television microwave communications. Drake has suggested that we ought to scan stars systematically and look for this same kind of effect, although it is much easier and much less expensive to just listen. Perhaps we ought to just systematically *listen*. A positive result could be the most exciting scientific discovery of all of human existence.

These discussions aren't entirely in the realm of science fiction. Serious scientists are discussing these things: If contact were made, what one could learn and what the philosophical impact of our realizing that man is not alone would be. I think the implications are profound.

When we look at the grandeur of our universe and the processes that have taken place, the grandeur of life and the beauty of life processes, and at the tiny speck of rock on which we live, it makes the quibblings and the arguments and the hatreds between individual groups of human beings seem rather inconsequential. Indeed, I feel that we might well be on the edge of a great tragedy. The tragedy would not just be the disappearance of a species. That would be tragic enough. The tragedy would be this: For the first time in the history of life on earth a creature has emerged which has the power to control his destiny and

which, above all, has the power to wonder and learn how the universe operates, and even to ask the philosopher's question, "Why?" And he has developed tools which enable him to answer these questions. Then the power for answering them is taken away from him by some kind of a major catastrophe of his own doing. This, I think, would be the grand tragedy of our earth and its entire evolution.

It is clear when we look at the power that science and technology have given us and at the problems which confront us, that from a purely technological point of view those problems can be solved. For example, our existing knowledge today makes starvation in the world inexcusable. We know how to *learn* how to grow much more food than we now know how to grow. Deprivation in the world is inexcusable. We have the technology to support a considerably higher population of human beings than now exists, at a level of abundance where all persons could be free from starvation and misery. But, although we know how to do this from a technological point of view, we do not yet know how to do it from a social or a political point of view.

Long ago we recognized that when we wanted to learn how to grow more food we supported agricultural research. When we wanted to learn how to make new weapons, we supported military research and we learned how to make new weapons. Somehow, in some way, we learned that basic research is needed as backup for research on these applied problems. Somehow a National Science Foundation was established, and basic research has been supported by individual government agencies in addition.

SOCIAL SCIENCE RESEARCH

This has all been in the natural sciences. When it comes to research on how individual human beings act with each other, when it comes to our learning how groups of individuals interact with each other, when it comes to the broad spectrum of social sciences, there's virtually no research! There is some, of course, but it is supported at a tiny level compared with the need and compared with the support given other areas of research endeavor.

There are many reasons for this, I suppose. Each one of us is our own psychologist and our own economist, and certainly we are all our own political scientist. Yet it is a constant source of wonder to me that there is no foundation supported by our government for research in the social sciences—that virtually none of the government agencies has the wherewithal, or none of them devotes whatever wherewithal it might have available to research in these areas. And yet when we look at the tremendous problems of population growth in advanced societies, the problems of urbanization, the problems of slums, of transportation—just the problems of people getting along with people—clearly the social component is as great or greater than the purely technological one.

The same thing is true when we look at the basic problems of the social and economic development in those vast areas of the world which are now living at starvation levels—where population is getting completely out of hand, and which threaten at any time to explode in a sequence of explosions which I think is going to pale Vietnam into insignificance.

IN SEARCH OF MEANING

I think all of the questions which have been raised bring up another important point. What really is the meaning and purpose of life? Is it just to get enough to eat? Is it just to get enough gadgets to put in our home? Is it just to reproduce—no matter how beautiful, intelligent, and free of disease the human beings might be who emerge from the factory Dr. Bonner is proposing?

No! I think that if there is any meaning and purpose to life it is learning what our universe is all about and what man's place in the universe is. All of these other things are really problems which stand in the way of that and are diversions from man's long-term goals of learning what we are, where we came from, where we're heading, and perhaps even why. I believe that the meaning and purpose of life was well phrased in words of Shakespeare's Hamlet when he asked:

> What is a man,
> If his chief good and market of his time
> Be but to sleep and feed? a beast, no more.
> Sure, he that made us with such large discourse,
> Looking before and after, gave us not
> That capability and god-like reason
> To fust in us unused.