The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

I.  Bernal's Book

***The World, The Flesh and the Devil; An Enquiry into the Future of the Three Enemies of the Rational Soul***, is the full title of Bernal's first book which he wrote at the age of 28.  Forty years later he said in a foreword to the second edition, “This short book was the first I ever wrote.  I have a great attachment to it because it contains many of the seeds of ideas which I have been elaborating throughout my scientific life.  It still seems to me to have validity in its own right.”  It must have been a consolation to Bernal, crippled and incapacitated in the last years of his life, to know that this work of his spring-time was again being bought and read by a new generation of young readers.

Bernal's book begins with these words:  “There are two futures, the future of desire and the future of fate, and man's reason has never learnt to separate them.”  I do not know of any finer opening sentence of a work of literature in English.  Bernal's modest claim that his book “still seems to have validity in its own right” holds good in 1972 as it did in 1968.  Enormous changes have occurred since he wrote the book in 1929, both in science and in human affairs.  It would be miraculous if nothing in it had become dated or superseded by the events of the last forty years.  But astonishingly little of it has proved to be wrong or irrelevant to our present concerns.

I decided that the best way I can do honor to Bernal in this lecture is to use his book as a point of departure for my own speculations about the future of mankind.  I shall not expound or criticize the book in detail.  I hope that much of what I shall say will be fresh and will go in some directions beyond Bernal's horizons.  But it will be obvious to those of my audience who have read Bernal that my ideas are deeply influenced by him.  To those of you who have not read Bernal I hope that I may provide a stimulus to do so.

Bernal saw the future as a struggle of the rational side of man's nature against three enemies.  The first enemy he called the World, meaning scarcity of material goods, inadequate land, harsh climate, desert, swamp, and other physical obstacles which condemn the majority of mankind to lives of poverty.  The second enemy he called the Flesh, meaning the defects in man's physiology that expose him to disease, cloud the clarity of his mind, and finally destroy him by senile deterioration.  The third enemy he called the Devil, meaning the irrational forces in man's psychological nature that distort his perceptions and lead him astray with crazy hopes and fears, overriding the feeble voice of reason.  Bernal had faith that the rational soul of man would ultimately prevail over these enemies.  But he did not foresee cheap or easy victories.  In each of these struggles, he saw hope of defeating the enemy only if mankind is prepared to adopt extremely radical measures.

Briefly summarized, the radical measures which Bernal prescribed were the following.  To defeat the World, the greater part of the human species will leave this planet and go to live in innumerable freely floating colonies scattered through outer space.  To defeat the Flesh, humans will learn to replace failing organs with artificial substitutes until we become an intimate symbiosis of brain and machine.  To defeat the Devil, we shall first reorganize society along scientific lines, and later learn to exercise conscious intellectual control over our moods and emotional drives, intervening directly in the affective functions of our brains with technical means yet to be discovered.  This summary is a crude oversimplification of Bernal's discussion.  He did not imagine that these remedies would provide a final solution to the problems of humanity.  He well knew that every change in the human situation will create new problems and new enemies of the rational soul.  He stopped where he stopped because he could not see any farther.  His chapter on “The Flesh” ends with the words:  “That may be an end or a beginning, but from here it is out of sight.”

How much that was out of sight to Bernal in 1929 can we see from the vantage point of 1972?  The first and most obvious difference between 1929 and 1972 is that we have now a highly vocal and well-organized opposition to the further growth of the part that technology plays in human affairs.  The social prophets of today look upon technology as a destructive rather than a liberating force.  In 1972 it is highly unfashionable to believe as Bernal did that the colonization of space, the perfection of artificial organs and the mastery of brain physiology are the keys to man's future.  Young people in tune with the mood of the times regard space as irrelevant, and they consider ecology to be the only branch of science that is ethically respectable.  However, it would be wrong to imagine that Bernal's ideas were more in line with popular views in 1929 than they are in 1972.  Bernal was never a man to swim with the tide.  Technology was unpopular in 1929 because it was associated in people's minds with the gas warfare of the first World War, just as now it is unpopular by association with Hiroshima and the defoliation of Vietnam.  In 1929 the dislike of technology was less noisy than today but no less real.  Bernal understood that his proposals for the remaking of man and society flew in the teeth of deeply entrenched human instincts.  He did not on that account weaken or compromise his statement.  He believed that a rational soul would ultimately come to accept his vision of the future as reasonable, and that for him was enough.  He foresaw that mankind might split into two species, one following the technological path which he described, the other holding on as best it could to the ancient folkways of natural living.  And he recognized that the dispersion of mankind into the vastness of space is precisely what is required for such a split of the species to occur without intolerable strife and social disruption.  The wider perspective which we have gained between 1929 and 1972 concerning the harmful effects of technology affects only the details and not the core of Bernal's argument.

Another conspicuous difference between 1929 and 1972 is that men have now visited the moon.  Surprisingly, this fact makes little difference to the plausibility of Bernal's vision of the future.  Bernal in 1929 foresaw cheap and massive emigration of human beings from the earth.  He did not know in detail how it should be done.  We still do not know how it should be done.  Certainly it will not be done by using the techniques that took men to the moon in 1969.  We know that in principle the cost in energy or fuel of transporting people from Earth into space need be no greater than the cost of transporting them from New York to London.  To translate this “in principle” into reality will require two things: first a great advance in the engineering of hypersonic aircraft, and second the growth of a traffic massive enough to permit large economies of scale.  It is likely that the Apollo vehicle bears the same relation to the cheap mass-transportation space-vehicle of the future as the majestic airship of the 1930s bears to the Boeing 747 of today.  The airship R101 was absurdly large, beautiful, expensive, and fragile, just like the Apollo Saturn 5.  If this analogy is sound, and I believe it is, we shall have transportation into space at a reasonable price within about fifty years from now.  But my grounds for believing this are not essentially firmer than Bernal's were for believing it in 1929.

© Copyright 1972, 1973, 2002 Freeman J. Dyson.  Reprinted by permission of author.

([Archive](http://impearls.blogspot.com/2002_11_10_archive.html#84393316))  ([Item](http://impearls.blogspot.com/2002/11/ii-double-helix.html))  Posted 01:57 UT by [Michael McNeil](mailto:Michael%20McNeil%20%3cMEMcNeil0@gmail.com%3e?Subject=[Impearls]%20)

The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

II.  The Double Helix

The decisive change that has enabled us to see farther in 1972 than we could in 1929 is the advent of molecular biology.  Bernal recognized this in the 1968 foreword to his book, where he speaks of the double helix as “the greatest and most comprehensive idea in all science.”  We now understand the basic principles by which living cells organize and reproduce themselves.  Many mysteries remain, but it is inevitable that we shall understand the chemical processes of life in full detail, including the processes of development and differentiation of higher organisms, within the next century.  I consider it also inevitable and desirable that we shall learn to exploit these processes for our own purposes.  The next century will see a completely new technology growing out of the mastery of the principles of biology in the same way as our existing technology grew out of a mastery of the principles of physics.

The new biological technology may grow in three distinct directions.  Probably all three will be followed and will prove fruitful for particular purposes.  The first direction is the one that has been chiefly discussed by biologists who feel responsibility for the human consequences of their work; they call it “genetic surgery.”  The idea is that we shall be able to read the base-sequence of the DNA in a human sperm or egg-cell, run the sequence through a computer which will identify deleterious genes or mutations, and then by micromanipulation patch harmless genes into the sequence to replace the bad ones.  It might also be possible to add to the DNA genes conferring various characteristics to the resulting individual.  This technology will be difficult and dangerous, and its use will raise severe ethical problems.  Jacques Monod in his recent book *Chance and Necessity* sweeps all thought of it aside with his customary dogmatic certitude.  “There are,” he says, “occasional promises of remedies expected from the current advances in molecular genetics.  This illusion, spread by a few superficial minds, had better be disposed of.”  Although I have a great respect for Jacques Monod, I still dare to brave his scorn by stating my belief that genetic surgery has an important part to play in man's future.  But I share the prevailing view of biologists that we must be exceedingly careful in interfering with the human genetic material.  The interactions between the thousands of genes in a human cell are so exquisitely complicated that a computer program labeling genes “good” or “bad” will be adequate to deal only with the grossest sort of defect.  There are strong arguments for declaring a moratorium on genetic surgery for the next hundred years, or until we understand human genetics vastly better than we do now.

Leaving aside genetic surgery applied to humans, I foresee that the coming century will place in our hands two other forms of biological technology which are less dangerous but still revolutionary enough to transform the conditions of our existence.  I count these new technologies as powerful allies in the attack on Bernal's three enemies.  I give them the names “biological engineering” and “self-reproducing machinery.”  Biological engineering means the artificial synthesis of living organisms designed to fulfill human purposes.  Self-reproducing machinery means the imitation of the function and reproduction of a living organism with nonliving materials, a computer program imitating the function of DNA and a miniature factory imitating the functions of protein molecules.  After we have attained a complete understanding of the principles of organization and development of a simple multicellular organism, both of these avenues of technological exploitation should be open to us.

© Copyright 1972, 1973, 2002 Freeman J. Dyson.  Reprinted by permission of author.

([Archive](http://impearls.blogspot.com/2002_11_10_archive.html#84392783))  ([Item](http://impearls.blogspot.com/2002/11/iii-biological-engineering.html))  Posted 01:46 UT by [Michael McNeil](mailto:Michael%20McNeil%20%3cMEMcNeil0@gmail.com%3e?Subject=[Impearls]%20)

The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

III.  Biological Engineering

I would expect the earliest and least controversial triumphs of biological engineering to be extensions of the art of industrial fermentation.  When we are able to produce microorganisms equipped with enzyme systems tailored to our own design, we can use such organisms to perform chemical operations with far greater delicacy and economy than present industrial practices allow.  For example, oil refineries would contain a variety of bugs designed to metabolize crude petroleum into the precise hydrocarbon stereo-isomers which are needed for various purposes.  One tank would contain the n-octane bug, another the benzene bug, and so on.  All the bugs would contain enzymes metabolizing sulphur into elemental form, so that pollution of the atmosphere by sulphurous gases would be completely controlled.  The management and operation of such fermentation tanks on a vast scale would not be easy, but the economic and social rewards are so great that I am confident we shall learn how to do it.  After we have mastered the biological oil refinery, more important applications of the same principles will follow.  We shall have factories producing specific foodstuffs biologically from cheap raw materials, and sewage-treatment plants converting our wastes efficiently into usable solids and pure water.  To perform these operations we shall need an armamentarium of many species of microorganisms trained to ingest and excrete the appropriate chemicals.  And we shall design into the metabolism of these organisms the essential property of self-liquidation, so that when deprived of food they disappear by cannibalizing one another.  They will not, like the bacteria that feed on our sewage in today's technology, leave their rotting carcasses behind to make a sludge only slightly less noxious than the mess they have eaten.

If these expectations are fulfilled, the advent of biological technology will help enormously in the establishment of patterns of industrial development with which human beings can live in health and comfort.  Oil refineries need not stink.  Rivers need not be sewers.  However, there are many environmental problems which the use of artificial organisms in enclosed tanks will not touch.  For example, the fouling of the environment by mining and by abandoned automobiles will not be reduced by building cleaner factories.  The second step in biological engineering, after the enclosed biological factory, is to let artificial organisms loose into the environment.  This is admittedly a more dangerous and problematical step than the first.  The second step should be taken only when we have a deep understanding of its ecological consequences.  Nevertheless the advantages which artificial organisms offer in the environmental domain are so great that we are unlikely to forego their use forever.

The two great functions which artificial organisms promise to perform for us when let loose upon the earth are mining and scavenging.  The beauty of a natural landscape undisturbed by man is largely due to the fact that the natural organisms in a balanced ecology are excellent miners and scavengers.  Mining is mostly done by plants and microorganisms extracting minerals from water, air, and soil.  For example, it has been recently discovered that organisms in the ground mine ammonia and carbon monoxide from air with high efficiency.  To the scavengers we owe the fact that a natural forest is not piled as high with dead birds as one of our junk yards with dead cars.  Many of the worst offenses of human beings against natural beauty are due to our incompetence in mining and scavenging.  Natural organisms know how to mine and scavenge effectively in a natural environment.  In a man-made environment, neither they nor we know how to do it.  But there is no reason why we should not be able to design artificial organisms that are adaptable enough to collect our raw materials and dispose of our refuse in an environment that is a careful mixture of natural and artificial.

A simple example of a problem that an artificial organism could solve is the eutrophication of lakes.  At present many lakes are being ruined by excessive growth of algae feeding on high levels of nitrogen or phosphorus in the water.  The damage could be stopped by an organism that would convert nitrogen to molecular form or phosphorus to an insoluble solid.  Alternatively and preferably, an organism could be designed to divert the nitrogen and phosphorus into a food chain culminating in some species of palatable fish.  To control and harvest the mineral resources of the lake in this way will in the long run be more feasible than to maintain artificially a state of “natural” barrenness.

The artificial mining organisms would not operate in the style of human miners.  Many of them would be designed to mine the ocean.  For example, oysters might extract gold from seawater and secrete golden pearls.  A less poetic but more practical possibility is the artificial coral that build a reef rich in copper or magnesium.  Other mining organisms would burrow like earthworms into mud and clay, concentrating in their bodies the ores of aluminum or tin or iron, and excreting the ores in some manner convenient for human harvesting.  Almost every raw material necessary for our existence can be mined from ocean, air or clay, without digging deep into the earth.  Where conventional mining is necessary, artificial organisms can still be useful for digesting and purifying the ore.

Not much imagination is needed to foresee the effectiveness of artificial organisms as scavengers.  A suitable microorganism could convert the dangerous organic mercury in our rivers and lakes to a harmless insoluble solid.  We could make good use of an organism with a consuming appetite for polyvinyl chloride and similar plastic materials which now litter beaches all over the earth.  Conceivably we may produce an animal specifically designed for chewing up dead automobiles.  But one may hope that the automobile in its present form will become extinct before it needs to be incorporated into an artificial foodchain.  A more serious and permanent role for scavenging organisms is the removal of trace quantities of radioactivity from the environment.  The three most hazardous radioactive elements produced in fission reactors are strontium, cesium, and plutonium.  These elements have long half-lives and will inevitably be released in small quantities so long as mankind uses nuclear fission as an energy source.  The long-term hazard of nuclear energy would be notably reduced if we had organisms designed to gobble up these three elements from water or soil and convert them into indigestible form.  Fortunately, none of these three elements is essential to our body chemistry, and it therefore does us no harm if they are made indigestible.

© Copyright 1972, 1973, 2002 Freeman J. Dyson.  Reprinted by permission of author.

([Archive](http://impearls.blogspot.com/2002_11_10_archive.html#84392045))  ([Item](http://impearls.blogspot.com/2002/11/iv-big-trees.html))  Posted 01:30 UT by [Michael McNeil](mailto:Michael%20McNeil%20%3cMEMcNeil0@gmail.com%3e?Subject=[Impearls]%20)

The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

IV.  Big Trees

I have spoken about the two first steps of biological engineering.  The first will transform our industry and the second will transform our earth-bound ecology.  It is now time to speak of the third step, which is the colonization of space.  I believe in fact that biological engineering is the essential tool which will make Bernal's dream of the expansion of mankind in space a practical possibility.

First I have to clear away a few popular misconceptions about space as a habitat.  It is generally considered that planets are important.  Except for Earth, they are not.  Mars is waterless, and the others are for various reasons basically inhospitable to man.  It is generally considered that beyond the sun's family of planets there is absolute emptiness extending for light years until you come to another star.  In fact it is likely that space around the solar system is populated by huge numbers of comets, small worlds a few miles in diameter, rich in water and the other chemicals essential to life.  We see one of these comets only when it happens to suffer a random perturbation of its orbit which sends it plunging close to the sun.  It seems that roughly one comet per year is captured into the region near the sun, where it eventually evaporates and disintegrates.  If we assume that the supply of distant comets is sufficient to sustain this process over the thousands of millions of years that the solar system has existed, then the total population of comets loosely attached to the sun must be numbered in the thousands of millions.  The combined surface area of these comets is then a thousand or ten thousand times that of Earth.  I conclude from these facts that comets, not planets, are the major potential habitat of life in space.  If it were true that other stars have as many comets as the sun, it then would follow that comets pervade our entire Galaxy.  We have no evidence either supporting or contradicting this hypothesis.  If true, it implies that our Galaxy is a much friendlier place for interstellar travelers than it is popularly supposed to be.  The average distance between habitable oases in the desert of space is not measured in light years, but is of the order of a light day or less.

I propose to you then an optimistic view of the Galaxy an an abode of life.  Countless millions of comets are out there, amply supplied with water, carbon, and nitrogen, the basic constituents of living cells.  We see when they fall close to the sun that they contain all the common elements necessary to our existence.  They lack only two essential requirements for human settlement, namely warmth and air.  And now biological engineering will come to our rescue.  We shall learn how to grow trees on comets.

To make a tree grow in airless space by the light of a distant sun is basically a problem of redesigning the skin of its leaves.  In every organism the skin is the crucial part which must be most delicately tailored to the demands of the environment.  The skin of a leaf in space must satisfy four requirements.  It must be opaque to far-ultraviolet radiation to protect the vital tissues from radiation damage.  It must be impervious to water.  It must transmit visible light to the organs of photosynthesis.  It must have extremely low emissivity for far-infrared radiation, so that it can limit loss of heat and keep itself from freezing.  A tree whose leaves possess such a skin should be able to take root and flourish upon any comet as near to the sun as the orbits of Jupiter and Saturn.  Farther out than Saturn the sunlight is too feeble to keep a simple leaf warm, but trees can grow at far greater distances if they provide themselves with compound leaves.  A compound leaf would consist of a photosynthetic part which is able to keep itself warm, together with a concave mirror part which itself remains cold but focuses concentrated sunlight upon the photosynthetic part.  It should be possible to program the genetic instructions of a tree to produce such leaves and orient them correctly toward the sun.  Many existing plants possess structures more complicated than this.

Once leaves can be made to function in space, the remaining parts of a tree — trunk, branches, and roots — do not present any great problems.  The branches must not freeze, and therefore the bark must be a superior heat insulator.  The roots will penetrate and gradually melt the frozen interior of the comet, and the tree will build its substance from the materials that the roots find there.  The oxygen which the leaves manufacture must not be exhaled into space; instead it will be transported down to the roots and released into the regions where men will live and take their ease among the tree trunks.  One question still remains.  How high can a tree on a comet grow?  The answer is surprising.  On any celestial body whose diameter is of the order of ten miles or less, the force of gravity is so weak that a tree can grow infinitely high.  Ordinary wood is strong enough to lift its own weight to an arbitrary distance from the center of gravity.  This means that from a comet of ten-mile diameter, trees can grow out for hundreds of miles, collecting the energy of sunlight from an area thousands of times as large as the area of the comet itself.  Seen from far away, the comet will look like a small potato sprouting an immense growth of stems and foliage.  When man comes to live on the comets, he will find himself returning to the arboreal existence of his ancestors.

We shall bring to the comets not only trees but a great variety of other flora and fauna to create for ourselves an environment as beautiful as ever existed on Earth.  Perhaps we shall teach our plants to make seeds which will sail out across the ocean of space to propagate life upon comets still unvisited by man.  Perhaps we shall start a wave of life which will spread from comet to comet without end until we have achieved the greening of the Galaxy.  That may be an end or a beginning, as Bernal said, but from here it is out of sight.

© Copyright 1972, 1973, 2002 Freeman J. Dyson.  Reprinted by permission of author.

([Archive](http://impearls.blogspot.com/2002_11_10_archive.html#84391106))  ([Item](http://impearls.blogspot.com/2002/11/v-self-reproducing-machinery.html))  Posted 01:08 UT by [Michael McNeil](mailto:Michael%20McNeil%20%3cMEMcNeil0@gmail.com%3e?Subject=[Impearls]%20)

The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

V.  Self-Reproducing Machinery

In parallel with our exploitation of biological engineering, we may achieve an equally profound industrial revolution by following the alternative route of self-reproducing machinery.  Self-reproducing machines are devices which have the multiplying and self-organizing capabilities of living organisms but are built of metal and computers instead of protoplasm and brains.  It was the mathematician John von Neumann who first demonstrated that self-reproducing machines are theoretically possible and sketched the logical principles underlying their construction.  The basic components of a self-reproducing machine are precisely analogous to those of a living cell.  The separation of function between genetic material (DNA) and enzymatic machinery (protein) in a cell corresponds exactly to the separation between software (computer programs) and hardware (machine tools) in a self-reproducing machine.

I assume that in the next century, partly imitating the processes of life and partly improving on them, we shall learn to build self-reproducing machines programmed to multiply, differentiate, and coordinate their activities as skillfully as the cells of a higher organism such as a bird.  After we have constructed a single egg machine and supplied it with the appropriate computer program, the egg and its progeny will grow into an industrial complex capable of performing economic tasks of arbitrary magnitude.  It can build cities, plant gardens, construct electric power-generating facilities, launch space ships, or raise chickens.  The overall programs and their execution will remain always under human control.

The effects of such a powerful and versatile technology on human affairs are not easy to foresee.  Used unwisely, it offers a rapid road to ecological disaster.  Used wisely, it offers a rapid alleviation of all the purely economic difficulties of mankind.  It offers to rich and poor nations alike a rate of growth of economic resources so rapid that economic constraints will no longer be dominant in determining how people are to live.  In some sense this technology will constitute a permanent solution of man's economic problems.  Just as in the past, when economic problems cease to be pressing, we shall find no lack of fresh problems to take their place.

It may well happen that on Earth, for aesthetic or ecological reasons, the use of self-reproducing machines will be strictly limited and the methods of biological engineering will be used instead wherever this alternative is feasible.  For example, self-reproducing machines could proliferate in the oceans and collect minerals for man's use, but we might prefer to have the same job done more quietly by corals and oysters.  If economic needs were no longer paramount, we could afford a certain loss of efficiency for the sake of a harmonious environment.  Self-reproducing machines may therefore play on Earth a subdued and self-effacing role.

The true realm of self-reproducing machinery will be in those regions of the solar system that are inhospitable to man.  Machines built of iron, aluminum, and silicon have no need of water.  They can flourish and proliferate on the moon or on Mars or among the asteroids, carrying out gigantic industrial projects at no risk to the earth's ecology.  They will feed upon sunlight and rock, needing no other raw material for their construction.  They will build in space the freely floating cities that Bernal imagined for human habitation.  They will bring oceans of water from the satellites of the outer planets, where it is to be had in abundance, to the inner parts of the solar system where it is needed.  Ultimately this water will make even the deserts of Mars bloom, and men will walk there under the open sky breathing air like the air of Earth.

Taking a long view into the future, I foresee a division of the solar system into two domains.  The inner domain, where sunlight is abundant and water scarce, will be the domain of great machines and governmental enterprises.  Here self-reproducing machines will be obedient slaves, and men will be organized in giant bureaucracies.  Outside and beyond the sunlit zone will be the outer domain, where water is abundant and sunlight scarce.  In the outer domain lie the comets where trees and men will live in smaller communities, isolated from each other by huge distances.  Here men will find once again the wilderness that they have lost on Earth.  Groups of people will be free to live as they please, independent of governmental authorities.  Outside and away from the sun, they will be able to wander forever on the open frontier that this planet no longer possesses.

© Copyright 1972, 1973, 2002 Freeman J. Dyson.  Reprinted by permission of author.

([Archive](http://impearls.blogspot.com/2002_11_10_archive.html#84389558))  ([Item](http://impearls.blogspot.com/2002/11/vi-devils-and-pilgrims.html))  Posted 00:34 UT by [Michael McNeil](mailto:Michael%20McNeil%20%3cMEMcNeil0@gmail.com%3e?Subject=[Impearls]%20)

The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

VI.  Devils and Pilgrims

I have spoken much about how we may deal with the World and the Flesh, and I have said nothing about how we may deal with the Devil.  Bernal also had difficulties with the Devil.  He admitted in the 1968 foreword to his book that the chapter on the Devil was the least satisfactory part of it.  The Devil will always find new varieties of human folly to frustrate our too rational dreams.

Instead of pretending that I have an antidote to the Devil's wiles, I will end this lecture with a discussion of the human factors that most obviously stand in the way of our achieving the grand designs which I have been describing.  When mankind is faced with an opportunity to embark on any great undertaking, there are always three main factors that devilishly hamper our efforts.  The first is an inability to define or agree upon our objectives.  The second is an inability to raise sufficient funds.  The third is the fear of a disastrous failure.  All three factors have been conspicuously plaguing the United States space program in recent years.  It is a remarkable testimony to the vitality of the program that these factors have still not succeeded in bringing it to a halt.  When we stand before the far greater enterprises of biological technology and space colonization that lie in our future, the same three factors will certainly rise again to confuse and delay us.

I want now to demonstrate to you by a historical example how these human factors may be overcome.  I shall quote from William Bradford, one of the Pilgrim Fathers, who wrote a book called *Of Plimoth Plantation* describing the history of the first English settlement in Massachusetts.  Bradford was governor of the Plymouth colony for 28 years.  He began to write his history ten years after the settlement.  His purpose in writing it was, as he said, “That their children may see with what difficulties their fathers wrestled in going through these things in their first beginnings.  As also that some use may be made hereof in after times by others in such like weighty employments.”  Bradford's work remained unpublished for two hundred years, but he never doubted that he was writing for the ages.

Here is Bradford describing the problem of man's inability to agree upon objectives.  The date is Spring 1620, the same year in which the Pilgrims were to sail.

But as in all businesses the acting part is most difficult, especially where the work of many agents must concur, so was it found in this.  For some of those that should have gone in England fell off and would not go; other merchants and friends that had offered to adventure their moneys withdrew and pretended many excuses; some disliking they went not to Guiana; others again would adventure nothing except they went to Virginia.  Some again (and those that were most relied on) fell in utter dislike with Virginia and would do nothing if they went thither.  In the midst of these distractions, they of Leyden who had put off their estates and laid out their moneys were brought into a great strait, fearing what issue these things would come to.

The next quotation deals with the perennial problem of funding.  Here Bradford is quoting a letter written by Robert Cushman, the man responsible for buying provisions for the Pilgrims' voyage.  He writes from Dartmouth on 17 August 1620, desperately late in the year, months after the ships ought to have started.

And Mr. Martin, he said he never received no money on those conditions; he was not beholden to the merchants for a pin, they were bloodsuckers, and I know not what.  Simple man, he indeed never made any conditions with the merchants, nor ever spake with them.  But did all that money fly to Hampton, or was it his own?  Who will go and lay out money so rashly and lavishly as he did, and never know how he comes by it or on what conditions?  Secondly, I told him of the alteration long ago and he was content, but now he domineers and said I had betrayed them into the hands of slaves; he is not beholden to them, he can set out two ships himself to a voyage.  When, good man?  He hath but £50 in and if he should give up his accounts he would not have a penny left him, as I am persuaded.  Friend, if ever we make a plantation, God works a miracle, especially considering how scant we shall be of victuals, and most of all ununited amongst ourselves and devoid of good tutors and regiment.

My last quotation describes the fear of disaster, as it appeared in the debate among the Pilgrims over their original decision to go to America.

Others again, out of their fears, objected against it and sought to divert from it; alleging many things, and those neither unreasonable nor improbable; as that it was a great design and subject to many inconceivable perils and dangers; as, besides the casualties of the sea (which none can be freed from), the length of the voyage was such as the weak bodies of women and other persons worn out with age and travail (as many of them were) could never be able to endure.  And yet if they should, the miseries of the land which they should be exposed unto, would be too hard to be borne and likely, some or all of them together, to consume and utterly to ruinate them.  For there they should be liable to famine and nakedness and the want, in a manner, of all things.  The change of air, diet, and drinking of water would infect their bodies with sore sicknesses and grievous diseases.  And also those which should escape or overcome these difficulties should yet be in continual danger of the savage people, who are cruel, barbarous and most treacherous, being most furious in their rage and merciless where they overcome; not being content only to kill and take away life, but delight to torment men in the most bloody manner that may be.

I could go on quoting Bradford for hours, but this is not the place to do so.  What can we learn from him?  We learn that the three devils of disunity, shortage of funds, and fear of the unknown are no strangers to humanity.  They have always been with us and will always be with us whenever great adventures are contemplated.  From Bradford we learn too how they are to be defeated.  The Pilgrims used no technological magic to defeat them.  The Pilgrims' victory demanded the full range of virtues of which human beings under stress are capable; toughness, courage, unselfishness, foresight, common sense, and good humor.  Bradford would have set at the head of this list the virtue he considered most important, a faith in Divine Providence.

I end this sermon on a note of disagreement with Bernal.  Bernal believed that we shall defeat the Devil by means of a combination of socialist organization and applied psychology.  I believe that our best defense will be to rely on the human qualities that have remained unchanged from Bradford's time to ours.  If we are wise, we shall preserve intact these qualities of the human species through the centuries to come, and they will see us safely through the many crises of destiny that surely await us.  But I will let Bernal have the last word.  Bernal's last word is a question which William Bradford must often have pondered, but would not have known how to answer, as he watched the first generation of native born New Englanders depart from the ways of their fathers.

We hold the future still timidly, but perceive it for the first time, as a function of our own action.  Having seen it, are we to turn away from something that offends the very nature of our earliest desires, or is the recognition of our new powers sufficient to change those desires into the service of the future which they will have to bring about?

© Copyright 1972, 1973, 2002 Freeman J. Dyson.  Reprinted by permission of author.

\*\*\*\*\*\*\*

Impearls: 2002-11-10 Archive

Earthdate 2002-11-12

([Archive](http://impearls.blogspot.com/2002_11_10_archive.html#84429829))  ([Item](http://impearls.blogspot.com/2002/11/world-flesh-and-devil.html))  Posted 19:10 UT by [Michael McNeil](mailto:Michael%20McNeil%20%3cMEMcNeil0@gmail.com%3e?Subject=[Impearls]%20)

The World, The Flesh, and the Devil   by Freeman J. Dyson

*Freeman J. Dyson   
Institute for Advanced Study   
Princeton, New Jersey*

[Introduction](http://impearls.blogspot.com/2002_11_10_archive.html#TWTFATDIntro)  *by Michael McNeil*   
[I.  Bernal's Book](http://impearls.blogspot.com/2002_11_10_archive.html#84394162)   
[II.  The Double Helix](http://impearls.blogspot.com/2002_11_10_archive.html#84393316)   
[III.  Biological Engineering](http://impearls.blogspot.com/2002_11_10_archive.html#84392783)   
[IV.  Big Trees](http://impearls.blogspot.com/2002_11_10_archive.html#84392045)   
[V.  Self-Reproducing Machinery](http://impearls.blogspot.com/2002_11_10_archive.html#84391106)   
[VI.  Devils and Pilgrims](http://impearls.blogspot.com/2002_11_10_archive.html#84389558)

Introduction   by Michael McNeil

Glenn Reynolds, the [Instapundit](http://www.instapundit.com/), recently published in his web log several plugs for nanotechnology (not to speak of [entire articles](http://foxnews.com/story/0,2933,67119,00.html) appearing elsewhere), such as [this](http://www.instapundit.com/archives/005247.php#005247?) entitled “WHY WE NEED NANOTECHNOLOGY.”  In his piece, Reynolds quotes a [recent article](http://news.independent.co.uk/world/environment/story.jsp?story=347796) from *The Independent*, “Only technology revolution can save the Earth.”

Diplomacy has failed — meaning that only a revolutionary advanced technology will save the Earth from relentless global warming driven by greenhouse gas emissions, scientists warned yesterday.

Avoiding a catastrophic effect on climate from the burning of fossil fuels would require political will, international cooperation and huge resources, said the team from a group of American universities.  But “no amount of regulation” could solve the problem, they said.

I agree with Glenn Reynolds as to the great potential of nanotechnology, but I'd point out that there are several forthcoming technologies other specifically than nanotechnology which can greatly assist in ameliorating the (literally) vast problems, to which the quoted article alludes, facing us on this planet.

The best exposition of these new technologies of which I'm aware is a too-long-neglected essay by physicist-visionary Freeman Dyson, since 1953 of the Institute for Advanced Study in Princeton, originator of such concepts as the “Dyson sphere,” and the author of moving books such as *Disturbing the Universe* (1979), *Weapons and Hope* (1984), and *Infinite in All Directions* (1988).

Thirty years ago this year, on May 16, 1972, Freeman Dyson presented the Third J. D. Bernal Lecture, at Birkbeck College, London.  The talk was printed for private circulation in 1972 by Birkbeck College, and reprinted the following year as Appendix D of *Communication with Extraterrestrial Intelligence (CETI)*, edited by Carl Sagan and published by MIT Press.  Now three decades on the author has kindly allowed me to republish his essay here, slightly corrected from preceding versions.

Dyson's essay *The World, The Flesh, and the Devil* is a retro- and prospective look at the great physicist (and developer of X-ray crystallography) J. D. Bernal's first book, of similar name, composed in 1929.  In his talk dedicated to Bernal, Dyson said he decided the best way he can “do honor to Bernal … is to use his book as a point of departure for my own speculations about the future of mankind,” which Dyson certainly accomplishes in this essay.

How well do Dyson's (and Bernal's) predictions hold up over a span of 30 more years?  My view, just as Dyson said in his turn of Bernal, speaking then 43 years after Bernal had set down his book, is that the bright promise of the technologies championed is just as beckoning, and as yet as unrealized, as almost in Bernal's day.  (Of course, nanotechnology is another unrealized dream as yet, except for tentative beginnings.)

Someday, however, the technologies Dyson so eloquently lays out will be achieved.  They certainly appear possible, and I believe they are very likely both attainable and feasible, every one of them.  Look at the advances in biotechnology and computer systems over the past 30 years for slight guidance as to what can perhaps be achieved in derivative fields given a few more decades.

The conclusions of another great figure, physiologist and geneticist J. B. S. Haldane (writing in nearly the same period as when J. D. Bernal composed his own slim little book) are still pertinent in this regard, I believe, even today.

We are at present almost completely ignorant of biology, a fact which often escapes the notice of biologists, and renders them too presumptuous in their estimates of the present position of their science, too modest in their claims for the future….  The conservative has but little to fear from the man whose reason is the servant of his passions, but let him beware of him in whom reason has become the greatest and most terrible of the passions.  These are the wreckers of outworn empires and civilizations, doubters, disintegrators, deicides….  I do not say that biologists as a general rule try to imagine in any detail the future applications of their science.  They do not see themselves as sinister or revolutionary figures.  They have no time to dream.  But I suspect that more of them dream than would care to confess it….    
(J. B. S. Haldane, *Daedalus, or Science and the Future*, 1924)

Given the travails and wrenching transitions that no doubt lie ahead, the virtues of the pilgrim fathers that Dyson recommends to us in chapter [VI. Devils and Pilgrims](http://impearls.blogspot.com/2002_11_10_archive.html#84389558) will stand us in very good stead, in the future as they have in the past.

Without further ado, here's Freeman Dyson's *The World, The Flesh, and the Devil* (1972).  (Chapters are posted in inverse chronological order so scrolling down reads normally.)

[UPDATE](http://impearls.blogspot.com/2002_11_24_impearls_archive.html#85016886):  2002-11-24 19:34 UT:  Backlinks to linkers.