II

PROGRESS AND ENTROPY

As we have said, nature's statistical tendency to disorder, the tendency for entropy to increase in isolated systems, is expressed by the second law of thermodynamics. We, as human beings, are not isolated systems. We take in food, which generates energy, from the outside, and are, as a result, parts of that larger world which contains those sources of our vitality. But even more important is the fact that we take in information through our sense organs, and we act on information received.

Now the physicist is already familiar with the significance of this statement as far as it concerns our relations with the environment. A brilliant expression of the role of information in this respect is provided by Clerk Maxwell, in the form of the so-called "Maxwell demon," which we may describe as follows.

Suppose that we have a container of gas, whose temperature is everywhere the same. Some molecules of this gas will be moving faster than others. Now let us suppose that there is a little door in the container that lets the gas into a tube which runs to a heat engine, and that the exhaust of this heat engine is connected by another tube back to the gas chamber, through another door. At each door there is a little being with the power of watching the on-coming molecules and of opening or closing the doors in accordance with their velocity.

The demon at the first door opens it only for high-speed molecules and closes it in the face of low-speed molecules coming from the container. The role of the demon at the second door is exactly the opposite: he opens the door only for low-speed molecules coming from the container and closes it in the face of high-speed molecules. The result is that the temperature goes up at one end and down at the other thus creating a perpetual motion of "the second kind": that is, a perpetual motion which does not violate the first law of thermodynamics, which tells us that the amount of energy within a given system is constant, but does violate the second law of thermodynamics, which tells us that energy spontaneously runs down hill in temperature. In other words, the Maxwell demon seems to overcome the tendency of entropy to increase.

Perhaps I can illustrate this idea still further by considering a crowd milling around in a subway at two turnstiles, one of which will only let people out if they are observed to be running at a certain speed, and the other of which will only let people out if they are moving slowly. The fortuitous movement of the people in the subway will show itself as a stream of fast-moving people coming from the first turnstile, whereas the second turnstile will only let through slow-moving people. If these two turnstiles are connected by a passageway with a treadmill in it, the fast-moving people will have a greater tendency to turn the treadmill in one direction than the slow people to turn it in the other, and we shall gather a source of useful energy in the fortuitous milling around of the crowd.

Here there emerges a very interesting distinction between the physics of our grandfathers and that of the present day. In nineteenth century physics, it seemed to cost nothing to get information. The result is that there is nothing in Maxwell's physics to prevent one of his demons from furnishing its own power source. Modern physics, however, recognizes that the demon can only gain the information with which it opens or closes the door from something like a sense organ which for these purposes is an eye. The light that strikes the demon's eyes is not an energy-less supplement of mechanical motion, but shares in the main properties of mechanical motion itself. Light cannot be received by any instrument unless it hits it, and cannot indicate the position of any particle unless it hits the particle as well. This means, then, that even from a purely mechanical point of view we cannot consider the gas chamber as containing mere gas, but rather gas and light which may or may not be in equilibrium. If the gas and the light are in equilibrium, it can be shown as a consequence of present physical doctrine that the Maxwell demon will be as blind as if there were no light at all. We shall have a cloud of light coming from every direction, giving no indication of the position and momenta of the gas particles. Therefore the Maxwell demon will work only in a system that is not in equilibrium. In such a system, however, it will turn out that the constant collision between light and gas particles tends to bring the light and particles to an equilibrium. Thus while the demon may temporarily reverse the usual direction of entropy, ultimately it too will wear down.

The Maxwell demon can work indefinitely only if additional light comes from outside the system and does not correspond in temperature to the mechanical temperature of the particles themselves. This is a situation which should be perfectly familiar to us, because we see the universe around us reflecting light from the sun, which is very far from being in equilibrium with mechanical systems on the earth. Strictly speaking, we are confronting particles whose temperature is 50 or 60° F. with a light which comes from a sun at many thousands of degrees.

In a system which is not in equilibrium, or in part of such a system, entropy need not increase. It may, in fact, decrease locally. Perhaps this non-equilibrium of the world about us is merely a stage in a downhill course which will ultimately lead to equilibrium. Sooner or later we shall die, and it is highly probable that the whole universe around us will die the heat death, in which the world shall be reduced to one vast temperature equilibrium in which nothing really new ever happens. There will be nothing left but a drab uniformity out of which we can expect only minor and insignificant local fluctuations.

But we are not yet spectators at the last stages of the world's death. In fact these last stages can have no spectators. Therefore, in the world with which we are immediately concerned there are stages which, though they occupy an insignificant fraction of eternity, are of great significance for our purposes, for in them entropy does not increase and organization and its correlative, information, are being built up.

What I have said about these enclaves of increasing organization is not confined merely to organization as exhibited by living beings. Machines also contribute to a local and temporary building up of information, notwithstanding their crude and imperfect organization compared with that of ourselves.

Here I want to interject the semantic point that such words as life, purpose, and soul are grossly inadequate to precise scientific thinking. These terms have gained their significance through our recognition of the unity of a certain group of phenomena, and do not in fact furnish us with any adequate basis to characterize this unity. Whenever we find a new phenomenon which partakes to some degree of the nature of those which we have already termed "living phenomena," but does not conform to all the associated aspects which define the term "life," we are faced with the problem whether to enlarge the word "life" so as to include them, or to define it in a more restrictive way so as to exclude them. We have encountered this problem in the past in considering viruses, which show some of the tendencies of life—to persist, to multiply, and to organize—but do not express these tendencies in a fully developed form. Now that certain analogies of behavior are being observed between the machine and the living organism, the problem as to whether the machine is alive or not is, for our purposes, semantic and we are at liberty to answer it one way or the other as best suits our convenience. As Humpty Dumpty says about some of his more remarkable words, "I pay them extra, and make them do what I want."

If we wish to use the word "life" to cover all phenomena which locally swim upstream against the current of increasing entropy, we are at liberty to do so. However, we shall then include many astronomical phenomena which have only the shadiest resemblance to life as we ordinarily know it. It is in my opinion, therefore, best to avoid all question-begging epithets such as "life," "soul," "vitalism," and the like, and say merely in connection with machines that there is no reason why they may not resemble human beings in representing pockets of decreasing entropy in a framework in which the large entropy tends to increase.

When I compare the living organism with such a machine, I do not for a moment mean that the specific physical, chemical, and spiritual processes of life as we ordinarily know it are the same as those of life-imitating machines. I mean simply that they both can exemplify locally anti-entropic processes, which perhaps may also be exemplified in many other ways which we should naturally term neither biological nor mechanical.

While it is impossible to make any universal statements concerning life-imitating automata in a field which is growing as rapidly as that of automatization, there are some general features of these machines as they actually exist that I should like to emphasize. One is that they are machines to perform some definite task or tasks, and therefore must possess effector organs (analogous to arms and legs in human beings) with which such tasks can be performed. The second point is that they must be *en rapport* with the outer world by sense organs, such as photoelectric cells and thermometers, which not only tell them what the existing circumstances are, but enable them to record the performance or nonperformance of their own tasks. This last function, as we have seen, is called *feedback*, the property of being able to adjust future conduct by past performance. Feedback may be as simple as that of the common reflex, or it may be a higher order feedback, in which past experience is used to regulate not only specific movements, but also whole policies of behavior. Such a policy-feedback may, and often does, appear to be what we know under one aspect as a conditioned reflex, and under another as learning.

For all these forms of behavior, and particularly for the more complicated ones, we must have central decision organs which determine what the machine is to do next on the basis of information fed back to it, which it stores by means analogous to the memory of a living organism.

It is easy to make a simple machine which will run toward the light or run away from it, and if such machines also contain lights of their own, a number of them together will show complicated forms of social behavior such as have been described by Dr. Grey Walter in his book, *The Living Brain.* At present the more complicated machines of this type are nothing but scientific toys for the exploration of the possibilities of the machine itself and of its analogue, the nervous system. But there is reason to anticipate that the developing technology of the near future will use some of these potentialities.

Thus the nervous system and the automatic machine are fundamentally alike in that they are devices which make decisions on the basis of decisions they have made in the past. The simplest mechanical devices will make decisions between two alternatives, such as the closing or opening of a switch. In the nervous system, the individual nerve fiber also decides between carrying an impulse or not. In both the machine and the nerve, there is a specific apparatus for making future decisions depend on past decisions, and in the nervous system a large part of this task is done at those extremely complicated points called "synapses" where a number of incoming nerve fibers connect with a single outgoing nerve fiber. In many cases it is possible to state the basis of these decisions as a threshold of action of the synapse, or in other words, by telling how many incoming fibers should fire in order that the outgoing fibers may fire.

This is the basis of at least part of the analogy between machines and living organisms. The synapse in the living organism corresponds to the switching device in the machine. For further development of the detailed relationship between machines and living organisms, one should consult the extremely inspiring books of Dr. Walter and Dr. W. Ross Ashby.[1]

The machine, like the living organism, is, as I have said, a device which locally and temporarily seems to resist the general tendency for the increase of entropy. By its ability to make decisions it can produce around it a local zone of organization in a world whose general tendency is to run down.

[1] W. Ross Ashby, *Design for a Brain*, Wiley, New York, 1952, and W. Grey Walter, *The Living Brain*, Norton, New York, 1953.

The scientist is always working to discover the order and organization of the universe, and is thus playing a game against the arch enemy, disorganization. Is this devil Manichaean or Augustinian? Is it a contrary force opposed to order or is it the very absence of order itself? The difference between these two sorts of demons will make itself apparent in the tactics to be used against them. The Manichaean devil is an opponent, like any other opponent, who is determined on victory and will use any trick of craftiness or dissimulation to obtain this victory. In particular, he will keep his policy of confusion secret, and if we show any signs of beginning to discover his policy, he will change it in order to keep us in the dark. On the other hand, the Augustinian devil, which is not a power in itself, but the measure of our own weakness, may require our full resources to uncover, but when we have uncovered it, we have in a certain sense exorcised it, and it will not alter its policy on a matter already decided with the mere intention of confounding us further. The Manichaean devil is playing a game of poker against us and will resort readily to bluffing; which, as von Neumann explains in his *Theory of Games,* is intended not merely to enable us to win on a bluff, but to prevent the other side from winning on the basis of a certainty that we will not bluff.

Compared to this Manichaean being of refined malice, the Augustinian devil is stupid. He plays a difficult game, but he may be defeated by our intelligence as thoroughly as by a sprinkle of holy water.

As to the nature of the devil, we have an aphorism of Einstein's which is more than an aphorism, and is really a statement concerning the foundations of scientific method. "The Lord is subtle, but he isn't simply mean." Here the word "Lord" is used to describe those forces in nature which include what we have attributed to his very humble servant, the Devil, and Einstein means to say that these forces do not bluff. Perhaps this devil is not far in meaning from Mephistopheles. When Faust asked Mephistopheles what he was, Mephistopheles replied, "A part of that force which always seeks evil and always does good." In other words, the devil is not unlimited in his ability to deceive, and the scientist who looks for a positive force determined to confuse us in the universe which he is investigating is wasting his time. Nature offers resistance to decoding, but it does not show ingenuity in finding new and undecipherable methods for jamming our communication with the outer world.

This distinction between the passive resistance of nature and the active resistance of an opponent suggests a distinction between the research scientist and the warrior or the game player. The research physicist has all the time in the world to carry out his experiments, and he need not fear that nature will in time discover his tricks and method and change her policy. Therefore, his work is governed by his best moments, whereas a chess player cannot make one mistake without finding an alert adversary ready to take advantage of it and to defeat him. Thus the chess player is governed more by his worst moments than by his best moments. I may be prejudiced about his claim: for I have found it possible myself to do effective work in science, while my chess has been continually vitiated by my carelessness at critical instants.

The scientist is thus disposed to regard his opponent as an honorable enemy. This attitude is necessary for his effectiveness as a scientist, but tends to make him the dupe of unprincipled people in war and in politics. It also has the effect of making it hard for the general public to understand him, for the general public is much more concerned with personal antagonists than with nature as an antagonist.

We are immersed in a life in which the world as a whole obeys the second law of thermodynamics: confusion increases and order decreases. Yet, as we have seen, the second law of thermodynamics, while it may be a valid statement about the whole of a closed system, is definitely not valid concerning a non-isolated part of it. There are local and temporary islands of decreasing entropy in a world in which the entropy as a whole tends to increase, and the existence of these islands enables some of us to assert the existence of progress. What can we say about the general direction of the battle between progress and increasing entropy in the world immediately about us?

The Enlightenment, as we all know, fostered the idea of progress, even though there were among the men of the eighteenth century some who felt that this progress was subject to a law of diminishing returns, and that the Golden Age of society would not differ very much from what they saw about them. The crack in the fabric of the Enlightenment, marked by the French Revolution, was accompanied by doubts of progress elsewhere. Malthus, for example, sees the culture of his age about to sink into the slough of an uncontrolled increase in population, swallowing up all the gains so far made by humanity.

The line of intellectual descent from Malthus to Darwin is clear. Darwin's great innovation in the theory of evolution was that he conceived of it not as a Lamarckian spontaneous ascent from higher to higher and from better to better, but as a phenomenon in which living beings showed (a) a spontaneous tendency to develop in many directions, and (b) a tendency to follow the pattern of their ancestors. The combination of these two effects was to prune an overlush developing nature and to deprive it of those organisms which were ill-adapted to their environment, by a process of "natural selection." The result of this pruning was to leave a residual pattern of forms of life more or less well adapted to their environment. This residual pattern, according to Darwin, assumes the appearance of universal purposiveness.

The concept of a residual pattern has come to the fore again in the work of Dr. W. Ross Ashby. He uses it to explain the concept of machines that learn. He points out that a machine of rather random and haphazard structure will have certain near-equilibrium positions, and certain positions far from equilibrium, and that the near-equilibrium patterns will by their very nature last for a long time, while the others will appear only temporarily. The result is that in Ashby's machine, as in Darwin's nature, we have the appearance of a purposefulness in a system which is not purposefully constructed simply because purposelessness is in its very nature transitory. Of course, in the long run, the great trivial purpose of maximum entropy will appear to be the most enduring of all. But in the intermediate stages an organism or a society of organisms will tend to dally longer in those modes of activity in which the different parts work together, according to a more or less meaningful pattern.

I believe that Ashby's brilliant idea of the unpurposeful random mechanism which seeks for its own purpose through a process of learning is not only one of the great philosophical contributions of the present day, but will lead to highly useful technical developments in the task of automatization. Not only can we build purpose into machines, but in an overwhelming majority of cases a machine designed to avoid certain pitfalls of breakdown will look for purposes which it can fulfill.

Darwin's influence on the idea of progress was not confined to the biological world, even in the nineteenth century. All philosophers and all sociologists draw their scientific ideas from the sources available at their time. Thus it is not surprising to find that Marx and his contemporary socialists accepted a Darwinian point of view in the matter of evolution and progress.

In physics, the idea of progress opposes that of entropy, although there is no absolute contradiction between the two. In the forms of physics directly dependent on the work of Newton, the information which contributes to progress and is directed against the increase of entropy may be carried by extremely small quantities of energy, or perhaps even by no energy at all. This view has been altered in the present century by the innovation in physics known as *quantum theory*.

Quantum theory has led, for our purposes, to a new association of energy and information. A crude form of this association occurs in the theories of line noise in a telephone circuit or an amplifier. Such background noise may be shown to be unavoidable, as it depends on the discrete character of the electrons which carry the current; and yet it has a definite power of destroying information. The circuit therefore demands a certain amount of communication power in order that the message may not be swamped by its own energy. More fundamental than this example is the fact that light itself has an atomic structure, and that light of a given frequency is radiated in lumps which are known as light quanta, which have a determined energy dependent on that frequency. Thus there can be no radiation of less energy than a single light quantum. The transfer of information cannot take place without a certain expenditure of energy, so that there is no sharp boundary between energetic coupling and informational coupling. Nevertheless, for most practical purposes, a light quantum is a very small thing; and the amount of energy transfer which is necessary for an effective informational coupling is quite small. It follows that in considering such a local process as the growth of a tree or of a human being, which depends directly or indirectly on radiation from the sun, an enormous local decrease in entropy may be associated with quite a moderate energy transfer. This is one of the fundamental facts of biology; and in particular of the theory of photosynthesis, or of the chemical process by which a plant is enabled to use the sun's rays to form starch, and other complicated chemicals necessary for life, out of the water and the carbon dioxide of the air.

Thus the question of whether to interpret the second law of thermodynamics pessimistically or not depends on the importance we give to the universe at large, on the one hand, and to the islands of locally decreasing entropy which we find in it, on the other. Remember that we ourselves constitute such an island of decreasing entropy, and that we live among other such islands. The result is that the normal prospective difference between the near and the remote leads us to give far greater importance to the regions of decreasing entropy and increasing order than to the universe at large. For example, it may very well be that life is a rare phenomenon in the universe; confined perhaps to the solar system, or even, if we consider life on any level comparable to that in which we are principally interested, to the earth alone. Nevertheless, we live on this earth, and the possible absence of life elsewhere in the universe is of no great concern to us, and certainly of no concern proportionate to the overwhelming size of the remainder of the universe.

Again, it is quite conceivable that life belongs to a limited stretch of time; that before the earliest geological ages it did not exist, and that the time may well come when the earth is again a lifeless, burnt-out, or frozen planet. To those of us who are aware of the extremely limited range of physical conditions under which the chemical reactions necessary to life as we know it can take place, it is a foregone conclusion that the lucky accident which permits the continuation of life in any form on this earth, even without restricting life to something like human life, is bound to come to a complete and disastrous end. Yet we may succeed in framing our values so that this temporary accident of living existence, and this much more temporary accident of human existence, may be taken as all-important positive values, notwithstanding their fugitive character.

In a very real sense we are shipwrecked passengers on a doomed planet. Yet even in a shipwreck, human decencies and human values do not necessarily vanish, and we must make the most of them. We shall go down, but let it be in a manner to which we may look forward as worthy of our dignity.

Up to this point we have been talking of a pessimism which is much more the intellectual pessimism of the professional scientist than an emotional pessimism which touches the layman. We have already seen that the theory of entropy, and the considerations of the ultimate heat-death of the universe, need not have such profoundly depressing moral consequences as they seem to have at first glance. However, even this limited consideration of the future is foreign to the emotional euphoria of the average man, and particularly to that of the average American. The best we can hope for the role of progress in a universe running downhill as a whole is that the vision of our attempts to progress in the face of overwhelming necessity may have the purging terror of Greek tragedy. Yet we live in an age not over-receptive to tragedy.

The education of the average American child of the upper middle class is such as to guard him solicitously against the awareness of death and doom. He is brought up in an atmosphere of Santa Claus; and when he learns that Santa

Claus is a myth, he cries bitterly. Indeed, he never fully accepts the removal of this deity from his Pantheon, and spends much of his later life in the search for some emotional substitute.

The fact of individual death, the imminence of calamity, are forced upon him by the experiences of his later years. Nevertheless, he tries to relegate these unfortunate realities to the role of accidents, and to build up a Heaven on Earth in which unpleasantness has no place. This Heaven on Earth consists for him in an eternal progress, and a continual ascent to Bigger and Better Things.

Our worship of progress may be discussed from two points of view: a factual one and an ethical one—that is, one which furnishes standards for approval and disapproval. Factually, it asserts that the earlier advance of geographical discovery, whose inception corresponds to the beginning of modern times, is to be continued into an indefinite period of invention, of the discovery of new techniques for controlling the human environment. This, the believers in progress say, will go on and on without any visible termination in a future not too remote for human contemplation. Those who uphold the idea of progress as an ethical principle regard this unlimited and quasi-spontaneous process of change as a *Good Thing,* and as the basis on which they guarantee to future generations a Heaven on Earth. It is possible to believe in progress as a fact without believing in progress as an ethical principle; but in the catechism of many Americans, the one goes with the other.

Most of us are too close to the idea of progress to take cognizance either of the fact that this belief belongs only to a small part of recorded history, or of the other fact, that it represents a sharp break with our own religious professions and traditions. Neither for the Catholic, the Protestant, nor for the Jew, is the world a *good* place in which an enduring happiness is to be expected. The church offers its pay for virtue, not in any coin which passes current among the Kings of the Earth, but as a promissory note on Heaven.

In essence, the Calvinist accepts this too, with the additional dark note that the Elect of God who shall pass the dire final examination of Judgment Day are few, and are to be selected by His arbitrary decree. To secure this, no virtues on earth, no moral righteousness, may be expected to be of the slightest avail. Many a good man will be damned. The blessedness which the Calvinists do not expect to find for themselves even in Heaven, they certainly do not await on earth.

The Hebrew prophets are far from cheerful in their evaluation of the future of mankind, or even of their chosen Israel; and the great morality play of Job, while it grants him a victory of the spirit, and while the Lord deigns to return to him his flocks and his servants and his wives, nevertheless gives no assurance that such a relatively happy outcome will take place except through the arbitrariness of God.

The Communist, like the believer in progress, looks for his Heaven on Earth, rather than as a personal reward to be drawn on in a post-earthly individual existence. Nevertheless, he believes that this Heaven on Earth will not come of itself without a struggle. He is just as skeptical of the Big Rock Candy Mountains of the Future as of the Pie in the Sky when you Die. Nor is Islam, whose very name means resignation to the will of God, any more receptive to the ideal of progress. Of Buddhism, with its hope for Nirvana and a release from the external Wheel of Circumstance, I need say nothing; it is inexorably opposed to the idea of progress, and this is equally true for all the kindred religions of India.

Besides the comfortable passive belief in progress, which many Americans shared at the end of the nineteenth century, there is another one which seems to have a more masculine, vigorous connotation. To the average American, progress means the winning of the West. It means the economic anarchy of the frontier, and the vigorous prose of Owen Wister and Theodore Roosevelt. Historically the frontier is, of course, a perfectly genuine phenomenon. For many years, the development of the United States took place against the background of the empty land that always lay farther to the West. Nevertheless, many of those who have waxed poetic concerning this frontier have been praisers of the past. Already in 1890, the census takes cognizance of the end of the true frontier conditions. The geographical limits of the great backlog of unconsumed and unbespoken resources of the country had clearly been set.

It is difficult for the average person to achieve an historical perspective in which progress shall have been reduced to its proper dimensions. The musket with which most of the Civil War was fought was only a slight improvement over that carried at Waterloo, and that in turn was nearly interchangeable with the Brown Bess of Marlborough's army in the Low Countries. Nevertheless, hand firearms had existed since the fifteenth century or earlier, and cannon more than a hundred years earlier still. It is doubtful whether the smoothbore musket ever much exceeded in range the best of the longbows, and it is certain that it never equaled them in accuracy nor in speed of fire; yet the longbow is the almost unimproved invention of the Stone Age.

Again, while the art of shipbuilding had by no means been completely stagnant, the wooden man-of-war, just before it left the seas, was of a pattern which had been fairly unchanged in its essentials since the early seventeenth century, and which even then displayed an ancestry going back many centuries more. One of Columbus' sailors would have been a valuable able seaman aboard Farragut's ships. Even a sailor from the ship that took Saint Paul to Malta would have been quite reasonably at home as a forecastle hand on one of Joseph Conrad's barks. A

Roman cattleman from the Dacian frontier would have made quite a competent *vaquero* to drive longhorn steers from the plains of Texas to the terminus of the railroad, although he would have been struck with astonishment with what he found when he got there. A Babylonian administrator of a temple estate would have needed no training either in bookkeeping or in the handling of slaves to run an early Southern plantation. In short, the period during which the main conditions of life for the vast majority of men have been subject to repeated and revolutionary changes had not even begun until the Renaissance and the great voyages, and did not assume anything like the accelerated pace which we now take for granted until well into the nineteenth century.

Under these circumstances, there is no use in looking anywhere in earlier history for parallels to the successful inventions of the steam engine, the steamboat, the locomotive, the modern smelting of metals, the telegraph, the transoceanic cable, the introduction of electric power, dynamite and the modern high explosive missile, the airplane, the electric valve, and the atomic bomb. The inventions in metallurgy which heralded the origin of the Bronze Age are neither so concentrated in time nor so manifold as to offer a good counter-example. It is very well for the classical economist to assure us suavely that these changes are purely changes in degree, and that changes in degree do not vitiate historic parallels. The difference between a medicinal dose of strychnine and a fatal one is also only one of degree.

Now, scientific history and scientific sociology are based on the notion that the various special cases treated have a sufficient similarity for the social mechanisms of one period to be relevant to those of another. However, it is certainly true that the whole scale of phenomena has changed sufficiently since the beginning of modern history to preclude any easy transfer to the present time of political, racial, and economic notions derived from earlier stages. What is almost as obvious is that the modern period beginning with the age of discovery is itself highly heterogeneous.

In the age of discovery Europe had become aware for the first time of the existence of great thinly-settled areas capable of taking up a population exceeding that of Europe itself; a land full of unexplored resources, not only of gold and silver but of the other commodities of commerce as well. These resources seemed inexhaustible, and indeed on the scale on which the society of 1500 moved, their exhaustion and the saturation of the population of the new countries were very remote. Four hundred and fifty years is farther than most people choose to look ahead.

However, the existence of the new lands encouraged an attitude not unlike that of Alice's Mad Tea Party. When the tea and cakes were exhausted at one seat, the natural thing for the Mad Hatter and the March Hare was to move on and occupy the next seat. When Alice inquired what would happen when they came around to their original positions again, the March Hare changed the subject. To those whose past span of history was less than five thousand years and who were expecting that the Millennium and the Final Day of Judgment might overtake them in far less time, this Mad Hatter policy seemed most sensible. As time passed, the tea table of the Americas has proved not to be inexhaustible; and as a matter of fact, the rate at which one seat has been abandoned for the next has been increasing at what is probably a still increasing pace.

What many of us fail to realize is that the last four hundred years are a highly special period in the history of the world. The pace at which changes during these years have taken place is unexampled in earlier history, as is the very nature of these changes. This is partly the result of increased communication, but also of an increased mastery over nature which, on a limited planet like the earth, may prove in the long run to be an increased slavery to nature. For the more we get out of the world the less we leave, and in the long run we shall have to pay our debts at a time that may be very inconvenient for our own survival. We are the slaves of our technical improvement and we can no more return a New Hampshire farm to the self-contained state in which it was maintained in 1800 than we can, by taking thought, add a cubit to our stature or, what is more to the point, diminish it. We have modified our environment so radically that we must now modify ourselves in order to exist in this new environment. We can no longer live in the old one. Progress imposes not only new possibilities for the future but new restrictions. It seems almost as if progress itself and our fight against the increase of entropy intrinsically must end in the downhill path from which we are trying to escape. Yet this pessimistic sentiment is only conditional upon our blindness and inactivity, for I am convinced that once we become aware of the new needs that a new environment has imposed upon us, as well as the new means of meeting these needs that are at our disposal, it may be a long time yet before our civilization and our human race perish, though perish they will even as all of us are born to die. However, the prospect of a final death is far from a complete frustration of life and this is equally true for a civilization and for the human race as it is for any of its component individuals. May we have the courage to face the eventual doom of our civilization as we have the courage to face the certainty of our personal doom. The simple faith in progress is not a conviction belonging to strength, but one belonging to acquiescence and hence to weakness.