

ON THE NATURE OF PROGRESS

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THE purpose of research is to promote progress; progress is going forward. Is it possible to know which way is forward? In physics there is a principle of relativity which asserts that it is not possible to know which way we are moving nor how fast. Is there a similar principle applicable to all progress? At any one time actions of many kinds are being suggested. The practical problem is to distinguish which of these are trivial and which are of epoch-making importance. Is this possible?

My interest in such matters arises from a lifelong habit of collecting opinions and observing whether these opinions are supported by subsequent events. One of my first examples was the development of the automobile. I felt that this might be important, and I asked everyone who would listen what he thought of the new machine. The only person I found who had the slightest interest in the matter was a professor of English who had some objection to the way the word was pronounced. Yet as a benefit to humanity it is now clear that the development of the automobile is comparable to any other single event in recorded history. For through the automobile, and its relatives the tractor and the truck, it became possible for a considerable number of people to live for the first time without excessively severe labor.

In the period since the development of the automobile I have noted similar failures to gauge the influence of current events. To cite a single instance, only a few years ago people in this country were required to limit production. They were paid for not raising pigs and directed to plow under every third row of cotton. It is true that some of our leaders protested against this policy of scarcity, but only on economic grounds. No one suggested that we didn't have enough of these things, that in a few years the progress of a great war would be slowed and lives lost through the lack of things people were being paid not to produce.

Experiences of this kind justify our considering whether it is possible in a significant way to estimate the future importance of present events. That such might be impossible follows from the fact that a logical conclusion can be reached only on a basis of complete information, and complete information is always lacking. Under these conditions the evidence can be twisted in a way to support the desired conclusion, and that is apparently done.

For example, during the First World War a petition was signed by many members of the M. I. T. faculty asking the United States Senate to cooperate with other governments in the establishment of a league of nations. When this paper reached me it carried a most distinguished list of faculty signatures. A short time later I asked a number of the signers, who were known to be Republicans, what they thought of the League, found that not a single one was supporting it. This is what had

happened; the campaign had first been for a "League to Enforce Peace," a movement led mainly by Republicans like Taft, Root, and Theodore Roosevelt. These faculty members had then thought the matter through and concluded that the league was a good thing. Later, Woodrow Wilson, a Democratic president, assumed leadership of the project. Then they thought the matter through again and decided it was not a good thing.

A few years ago it was customary to hold a peace meeting at M. I. T. almost every year. My liberal friends, in urging me to attend, stated that the purpose of the campaign was to get neutrality legislation which would prevent the American trusts getting us into war. In the last few years I haven't observed any of these Liberals worrying much about this possibility.

Now I am not adversely criticising these changes in attitude. If a million instances were given, undoubtedly the second choice would, on the average, be a little better than the first. I am merely questioning the possibility of a logical conclusion and citing as the first reason for doubt that rarely, if ever, is sufficient evidence available.

A second reason for doubting whether the future implications of present events can be foreseen is evidence that the future is not determined by the present and the past. A characteristic of logical determination is what is called continuity in mathematics. An indefinitely large result should not be produced by an indefinitely small cause. When such appears to be the case we say the result is unreasonable. This kind of unreasonableness is common, however, in everyday life.

For example, the world has been much disturbed in recent years by a man named Hitler. It is true that many of the objectionable things which have happened in Germany would have occurred if Hitler had never lived. But there are many others for which he was personally responsible, for instance, the effort to destroy the Jews. Some fifty years ago Hitler was merely a germ cell. If a few molecules had been removed at that time, Hitler would never have existed. When the lives and fortunes of millions of men are dependent on the fate of a single microscopical cell, causality in any worthwhile sense does not function.

All human affairs are thus subject to an indetermination principle. What will happen five minutes from now is pretty well determined, but as that period is gradually lengthened a larger and larger number of purely accidental occurrences are included. Ultimately a point is reached beyond which events are more than half determined by accidents which have not yet happened. Present planning loses significance when that point is reached.

My reason for making such obvious remarks is that although we admit the fact that no one can prophesy, yet governments are elected and assigned authority which can not be wisely used except by people possessing the gift of prophecy.

Here is the fundamental dilemma of civilization. Progress is the greatest thing there is; progress is going forward. Yet there is serious

doubt whether the way forward is known, and doubt even whether beyond a very brief interval any forward direction is determinate. What should be done about it?

This is not a new problem. Nature faced this problem millions of years ago, when it involved the improvement of the species. The mechanism used was mutation and cross-fertilization, and the problem was to utilize these processes to develop the best product. Nature solved the problem by leaving both processes to chance. If there had been a better way it seems certain that some species would have found it and used it for its own benefit. The fact that after millions of years this remains nature's way is strong evidence that there is no better way.

Translated into the realm of human affairs this means that progress is made by trial and error. In any process of trial and error the probability of a favorable result is proportional to the number of trials. If we would find the conditions most favorable to progress, the conditions under which the greatest number of things will be tried should be sought. The advances of which I am speaking are all mental. Such advances will be most frequent when the number of independent thought centers is greatest, and the number of thought centers will be greatest when there is maximum individual liberty. Thus it appears that maximum liberty is the condition most favorable to progress.

Throughout history orators and poets have extolled liberty, but no one has told us why liberty is so important. Our attitude toward such matters should depend on whether we consider civilization as fixed or as advancing. In a fixed society there ought to be best methods of doing things. Experts should be more capable of finding these methods than ordinary people, and, for the good of all the people, these methods should be put into effect by collective action. In such a society the practical problem is to obtain the best rulers; there is no need for individual liberty.

In an advancing society, however, any restriction on liberty reduces the number of things tried and so reduces the rate of progress. In such a society freedom of action is granted to the individual, not because it gives him greater satisfaction but because if allowed to go his own way he will on the average serve the rest of us better than under any orders we know how to give.

In some fields, however, this cannot be done, and progress is necessarily slow. An illustration of this is government. Anyone who reads Aristotle is impressed by his modern views concerning politics. His description of the various forms of government could be used with little change at the present time. But his remarks about physics are childish. In the period since Aristotle why has the science of physics developed so tremendously while the science of government has developed so little?

Some would answer that government is much more complex, but nothing I have seen suggests that government is any more complex than physics. The essential difference is that an individual can perform an experiment in physics, whereas it requires a whole nation to perform an

experiment in government. Since the important nations have populations of the order of a hundred million, this means that a hundred million times as many experiments can be performed in physics as in government. This piece of arithmetic contains the essential difficulty of all collective action.

In fact, the difficulty is even greater than is here suggested. The essential feature of experiment is that only one contributing factor is changed at a time, and the effect observed. In politics this is impossible. One system is tried this year, another next year. The weather will be different, there may be war or depression, a new invention may change the whole style of living, natural cyclic forces may produce large effects even if nothing is done by government. Over a long enough time these accidental variations average out, but the period is probably thousands of years.

Relative to such effects people may be compared with the molecules of a body, through which heat is passing. When observations are made upon the body—observations separated by minutes of time—we find that heat flows in a perfectly definite way from points of higher to points of lower temperature. Between two such observations occur billions of interactions between the molecules. If a molecule had intelligence and made observations in its immediate neighborhood, the direction of heat flow it would observe during a period of a few interactions would have no necessary relation to the flow as we see it. Similarly, if some supergiant, whose pulse beat once in a thousand years, should observe our civilization at intervals which to him are as minutes to us, he would observe a definite sequence of states. That sequence is progress. But we, observing at intervals of a few years, find only chaos.

Between the molecules and ourselves there is, however, one essential difference. Molecules are believed to be impelled by forces over which they have no control. Man believes, though no one has ever explained how, that to some extent he can choose what he shall do. To our actions is thus ascribed a moral quality which has no counterpart in the molecular realm. An action may be such as to aid the long term trend of progress. Such an action we might call moral, or good. An action may oppose that long term trend, and accordingly is immoral, or bad. From this point of view a code of morals is rated by its success in promoting progress.

So far I have stressed individual liberty as the basis of progress. Objection might be made that too much liberty leads to war and restrictions must be imposed to prevent war. I am strongly opposed to war and would support any reasonable scheme to prevent it. However, to succeed such a scheme must provide a substitute that is better than war. This is not easy to do since war has led to certain desirable results not easy to accomplish in other ways.

This condition has long been recognized by philosophical historians. For example, Hegel in his "Philosophy of History" in speaking of gunpowder says, "It was one of the chief instruments in freeing the world

from the dominion of physical force, and placing the various orders of society on a level. With the distinction between the weapons used vanished also that between lords and serfs." Hegel is referring to the gentry who in the Middle Ages wore iron clothes and waddled about Europe bullying the common people. When an ordinary man with a gun could send a bullet through their armor, iron clothes went out of fashion. Suppose the people who colonized this country had not had gunpowder. The development of the United States and the civilization of the world would have been set back centuries. Suppose again the development of arms had ended with the rifle. Imagine our troops conquering seventy million fanatical Japanese with nothing but the rifle. The cost in blood would be prohibitive.

At every step the development of arms has had the effect of placing political control in the hands of those technically strongest. Since these are also the people responsible for progress, this means that war has provided freedom to advance to those capable of making the advance. Any substitute for war which does not provide this freedom will encounter forces which throughout history have overridden all opposition.

But some would say that the destruction of war is so great that its prevention would justify even stopping progress. Let us examine that statement briefly. A fair way to do this is to note what would have happened if progress had ceased at some earlier date and there had been no war. Suppose, for example, conditions had remained static since 1901. Among other things this would mean no advances in public health. In 1901 the annual mortality rate in France was 20.1 per thousand. The highest mortality reached during the war was 18.6 in 1940, the year France was overcome, and this includes deaths from all causes including those due to war. Through the entire war period mortality rates in France thus remained materially lower than in 1901. In the United States there has been a decrease in the normal death rate since 1901 of about 6 per thousand. This means that the maintenance of the 1901 mortality rate would have taken more than 800,000 additional lives per year. The deaths due to war have never approached that figure. In England the experience has been about the same. In Germany reports just before the war indicated a mortality about 9 per thousand less than in 1901. The earlier mortality rates would have taken about 4,000,000 additional lives during the war period. Because of the unreliability of data in the countries at war an accurate estimate of mortality is impossible now. Since the reduction in mortality has been almost entirely in the younger years, the above figures make it probable that the average life expectation for the whole world has been better during the war than it would have been if the conditions of 1901 had continued. Meanwhile we have had the advantage of much better conditions during all the intervening peacetime years. This does not in the least diminish the tragedy of war. It does, however, suggest that lack of progress is even worse than war.

Unfortunately our views concerning such matters are influenced

more by dramatic features than by intrinsic importance. If an unknown drunken driver runs his automobile into a tree and is killed, the story will be headlined in the local papers. Almost every day important men die as the result of slightly antique medical practice and all the notice they get is a few lines in the death column. One effect of this tendency to dramatize news is that we take more interest in the things which seldom happen than in things which happen every day. If death in every case were traced to its initial cause the common cold would probably be found the greatest of all killers. Since there are persons with colds about us all the time, they attract little attention.

As a matter of fact the greatest misfortunes are not the things that do happen but the things that don't happen. Take, for example, the First World War, which it has been estimated cost about 8,000,000 lives. At that time we did not have penicillin. I have asked many people how many lives penicillin might save per year. The question is foolish but most people agree a million would be conservative. Assume that it is half that number. Between the First World War and the time penicillin was generally available it would then have saved at least 12,000,000 lives. And to this should be added most of those millions who died of influenza in the epidemic of 1918-19. At the time of the war, therefore, there were two misfortunes. We had the war and we did not have penicillin, but not having penicillin was clearly the greater misfortune. In fact the greatest misfortune the world has ever experienced consists in not having things which never yet have existed. But you are not going to get people much excited about some thing which doesn't exist when you can't even tell them what it is, the nonexistence of which you are worrying about.

Several times in this discussion I have spoken of progress as the greatest thing there is. Whether that is true or not depends on what still lies ahead. Many think we are near the final frontier of knowledge. Others think unlimited advances will continue. Our whole philosophy of life depends on whether we hold the one view or the other.

In attempting to estimate what is ahead many turn to speculation concerning new fields, such as atomic energy, which has now been so tragically demonstrated. A study of history, I believe, will show that in the past speculations have not been fruitful. The only prophecies that have been fulfilled are those of men, like Leonardo da Vinci, who didn't really prophesy but merely stated what they already dimly knew. Concerning the future I don't know anything, dimly or otherwise. Yet I should like to feel sure that unlimited progress is possible, and there is one type of advance which is unlimited and which involves no speculation, namely, advance through mere complication of what already exists.

A study of science indicates that the structures now used are of two types. First are those which involve only a small number of variables, each of which has an individual function. This includes most of present-day engineering. Second are structures which involve an uncountably large number of variables, but in which only average values are used. Such

are the atomic systems of thermodynamics and major fields of economics. Between these extremes are structures which involve a very large number of variables, each of which has an individual assignment. Illustrations are the hereditary units, or genes, in biology. A little consideration of the nature of numbers and combinations of numbers will show that this intermediate domain is indefinitely larger than the two ends.

Relative to such matters we are like the builder who might say "I know how to make perfect bricks, cities and towns are mere piles of brick." So we know how to make certain elementary combinations. Assembling these into structures of unlimited complexity is a work of the future.

In my own lifetime has occurred the development of every single thing which now distinguishes a high from a low standard of living. When I was born the telephone had been invented but was not in use. Electric power, the internal combustion engine, x-rays, moving pictures, the airplane, radio; even central heating, good roads, and a continuous supply of fresh food have all come since I was born. The world into which I was born was more like that of Julius Caesar than like that of the present day. If politics doesn't interfere I see no reason to doubt that when my son shall reach my present age he may again say, "Of all we have the better half has been developed during my lifetime." But if this rate of advance should continue forever the above analysis shows that unlimited further advance would always be possible, that the unknown would always infinitely transcend the known.