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23 October 1954

card

Dr. Vannevar Bush
Carnegie Institution of Washington
1530 P Street, N. W.
Washington 5, D. C.

Dear Van:

Many thanks for the copy of your lecture on Scientific Motivation. I have read it with the greatest interest.

At the moment I am smoking your pipe which is a constant reminder of you, and also reminds me that I should like to see you very soon.

Faithfully,

Allen W. Dulles
Director

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THE R. A. F. PENROSE, JR., MEMORIAL LECTURE

SCIENTIFIC MOTIVATION

VANNEVAR BUSH

President, Carnegie Institution of Washington

(*Read April 22, 1954*)

In a general lecture of this sort it is sometimes worth while to attempt to view the current status of scientific effort, to focus upon the crucial points where advance is most rapid, thus to catch a glimmer of where we stand and where we may now be headed, and on this basis to ponder on the motivation which urges us on. This is a difficult thing to do, and no two men will formulate alike even the present status of our understanding. Science is so vast, even when the discussion is confined to the natural sciences, the scene is so diverse in aspect, that such attempts often succeed merely in giving false impressions of simplicity. They are bound to leave out entirely areas from which the most important advances may emerge, they are bound to be colored by personal background, and, in place of a clear summary, they may merely produce more confusion. Yet the attempt may be worth while, if for no other reason, because it is refreshing to back out of the laboratory and the library and gaze out over the landscape. So, with full realization that every man will describe the landscape for himself and emphasize features dearest to him, with recognition that one can only pick and choose, let us take a look.

We need not spend much time with the physicists. They are busy digging into the nucleus of the atom, picking off a new elementary particle every few weeks, speaking a mathematical language which completely bars the unsophisticated from participating in the excitement of their delving. They seem to be having a very good time among themselves, but they have left the rest of us for a time; and we can merely hope they will later come up for air and tell us in a common language what it is all about. From a distance it appears that they may soon quit multiplying particles and tell us more about how one transforms into another, settling down perhaps again to a very few that are truly fundamental. We can sympathize with their difficulty in educating the rest of us; for, as they attack the forces binding the nucleus, their formulations necessarily take mathematical forms which have nothing to do with familiar things—nor should we expect them to. As they proceed there seems to be less of neo-Pythagoreanism among them, a bit less mysticism. One does not so often hear today that indeterminacy introduces chance into nature, provides a place for free will, denies causality. Rather it appears, more simply, merely to set a limit beyond which experimentation can no longer substantiate theory; and this limitation may provide permanent room for alternative formulations. Yet there seems to be no harm in this, and it does render the job interesting. So we may well leave the theoretical physicists to their own devices for a bit; it will be some time before we can understand them. And, when they toss out results which strongly affect other areas of effort, we shall certainly know about it, as we did when they split the atom into substantial pieces. In the meantime, classic physics is being left largely to the applied physicists and the engineers. It has become difficult to tell these two groups apart, just as it is often hard to tell a Democrat from a Republican. And classic physics is bounding forward, giving us new materials and new instruments, clarifying somewhat the solid state, giving birth to wholly new varieties of electronics, even beginning to make some sense out of the weather.

So, let us turn to a field where trends are much clearer and arguments are easier to grasp, where we look at large things rather than little ones. The cosmologists are having a field day; several road blocks have been removed, and they may be about to give us a consistent picture of the origins of the universe, its present status, and its future up to a point. There now seems to be a rapidly widening area of agreement among cosmologists, which is a phenomenon in itself. The red shift is widely regarded as showing a true expansion,

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as acceptable evidence that the galaxies are rushing away from us into space with velocities roughly proportional to their distances, rather than that light becomes weary in its long journey, or that cosmic dust nips off minute tributes in energy from the passing photons. The receding velocities are now measured up to 60 per cent of the velocity of light, or 180,000 kilometers per second. There is nothing sure about this theory of an expanding universe as yet; Finlay-Freundlich and Born have recently given pause by a theory which links the red shift with radio waves from space and leaves the astronomers merely measuring a temperature instead of a recession. But the reason why true expansion is now so generally accepted is not so much that insuperable difficulties are presented by alternative explanations of the red shift, as perhaps that the expansion hypothesis is so simple and leads so neatly to intriguing speculations on the mode of origin of the universe. There is now in process of refinement a new scale for the universe; for some of the early measurements have been found to be faulty, which is hardly surprising considering their nature; and the new scale brings the astronomers and the geophysicists nearer together on an estimate of about five billion years for the age of the visible universe. We are now told that, five billion years ago, there was nothing except a mass of nuclear fluid of enormous density and temperature. Then there was a tremendous explosion, and in the first thirty minutes following the explosion the elements were formed. What preposterous temerity—to analyze what happened in a half hour five billion years ago! Yet the hypothesis seems to work, and to yield correct figures for the ratios of elements we observe. Then a bit later, mutually receding clouds of gas condensed to form dust, and the galaxies separated and evolved. Stars were formed as the dust and gas condensed, and continue thus to be formed today. The old Kant-Laplace hypothesis comes to life, as Weizsäcker avoids the pitfall which once wrecked it—its failure to account for observed angular velocities—by taking into account turbulent motions and loss of hydrogen from the evolving system, thus obtaining results which correspond to the composition, spacing, angular velocities, and masses of the planets. Billions of stars are conceived to have been born in billions of galaxies, and it appears that planetary systems may have been frequently formed. There may, indeed, be millions of planets with conditions so nearly similar to those on earth that life such as we know would be possible, although perhaps still improbable. The life history of stars is also falling into line as the atomic energy cycles that maintain their brilliance become sorted out, although we as yet have very little idea why stars occasionally explode.

There are plenty of other mysteries left; for example, how a star can have an enormous, rapidly reversing magnetic field. We do not yet know the distance-speed relations of the galaxies at all well, or the variation of galaxy spacing with distance. It may take some time to find out, for we use the absolute magnitude of a galaxy to measure its distance. The light coming from the most remote galaxies that we can observe left them something like a billion years ago, and so we need to find out more about the variation of total light emission with age before the relations can be pinned down well. Thus we have no present measure of space curvature; neither can we say for sure that the velocities are such as to bar the hypothesis that expansion is a cyclic performance, although it appears as though the galaxies were leaving us, and every other point, irrevocably, and hence as though we were not just repeating over and over an explosion and subsequent collapse. If we do not wish to consider a universe that just bounces occasionally, we can consider, if we will, that space itself began with the primeval explosion, that we have a continually altering curvature of space, that we live in a three-dimensional bubble being blown up in a four-dimensional space. But, since we are three-dimensional beings, with three-dimensional minds, we can hardly expect to proceed at once to go much farther in our speculations. Nevertheless, the cosmologists are now giving us a logical, consistent pattern of the development of the universe. And in doing so they have obligingly allowed us plenty of further time on the earth for our speculations and formulations. We apparently do not need to hurry, except to fend off the disasters which we ourselves may create.

We also have a consistent and logical account of organic evolution on the earth, entirely on a mechanistic basis. Population genetics and its statistical treatment have placed natural selection on its feet so that there is no longer mystery in the gradual shifts or in the origin of new species. The story starts with the beginning of life in the fortuitous appearance of self-duplicating molecules in the primeval seas—still intangible in the haze of our ignorance of the Pre-Cambrian period—and proceeds from there. More complex forms appear as these special molecules combine into forms capable of seizing materials from their neighbors. There is no longer difficulty with the second law of thermodynamics as evolution thus produces more complex and apparently less probable states, for it is the organism plus its environment that constitutes a system, not the organism alone. Higher species appear, and evolution radiates to fill all available niches in the environment. There is also convergence, widely separated lines heading for the same niche, as when wings appear on pterodactyls, bats, and birds. Overspecialization occurs and species succumb. Intragroup selection sometimes carries characteristics to grotesque and deleterious extremes, and the coupling of genic systems may produce defects at the same time that it produces highly adaptive and favorable characters. When an opening in the environment appears because a group succumbs, it is often strikingly filled from the varied, crowding, evolving life about, and often again left open for a surprising length of time when no adjacent forms are ready to move in. Characteristics which appear to be evolved at random, and actually detrimental, persist in populations, and sometimes prove to be highly adaptive when the species shifts to a new environment, whereupon they become used and perfected. The interaction between environment and the statistical trend of the genetics of a population is by no means entirely worked out, but it appears that we have here the key which opens the door to a valid scheme of natural selection.

Everything I say would be contested in some quarters, for scientists are unanimous on very little. But there is today little tendency to call on vitalist or finalist theories to account for the marvelous variety and intricacy of living things. Thus the process of evolution is conceived to have proceeded mechanically for many hundreds of millions of years, until finally there appeared the primates and man. The evolutionists take the appearance of consciousness during this process in their stride, and the philosophers now seem to concentrate on nuts that are not so tough to crack as this one. So now we have conscious evolution, with man in partial control of his own destiny, with the exercise of a free will, tacitly accepted, appearing out of a wholly mechanistic evolutionary process, and in the common meaning foreign to its fundamental tenets.

Many of the old arguments concerning evolution have dissolved because of the remarkable progress in genetics. Wearying of sorting the genes of fruit-fly chromosomes, the geneticists turned to lower organisms, to bacteria and viruses, to find there the elementary beginnings of a complex system. And they found the same old complexity, with units of heredity, mutations, and all the rest. Moreover, reaching somewhat farther up the evolutionary scale, they now find the hereditary process to be more and more intricate. Multiple gene control of characteristics, cross influence of neighboring genes, genetic factors beyond the genes which control their action, even cytoplasmic inheritance appear. Mutagens, moreover, acting on bacteria, produce mutations over many generations; but this is not the inheritance of acquired characteristics in the old sense; it is direct action of environment on a genetic system long treated as though utterly immune to environmental influence. Specificity of mutagens does not appear strongly as yet, but it may. Gone is some of the old assurance, the dogmatism which could assert the general negative—that the environment has no influence on the hereditary mechanism—because a theory and a system had been constructed, mathematical in its precision, thought to be capable in full development of explaining everything. A set of genes, self-duplicating chemical compounds, occasionally mutating at random, immortal, passed from generation to generation without change and uninfluenced by the host, producing hormones which in turn controlled all development—this was much too simple and too pat. It is somewhat difficult to envisage the way in which such a mechanism could produce a bird with full individual knowledge of how to build a complex nest or to follow a pathway of migration, or a spider that could build a web. The day has not yet arrived when a student can embark upon examination of possible racial memory in a homing pigeon without encountering raised eyebrows. But geneticists are becoming more humble as their systems lead them deeper into intricacy; and this is well, for the story is only in its first chapter, and much hard work lies ahead before another Mendel can create a system adequate for the problems which confront us, many of which we now merely avoid.

All of life in its origin, growth, and hereditary mechanisms seems to revolve about the self-duplicating molecules, the proteins and the nucleic acids. These extraordinary chemical compounds, which can produce replicas of themselves out of the building blocks of their environment, lie at the heart of the great mysteries of life. A full understanding and a capability for adequate manipulation in this field call for a new type of chemistry which can deal with molecules of an atomic weight of a million, for a new type of special thinking, and for new aids to thinking. Some powerful aids are already available, in tracer techniques, chromatography, electronic instruments. Recently there has been a striking step forward, for Crick and Watson have presented a logical explanation of the mechanism by which a nucleic acid can form duplicates of itself in an appropriate medium. Soon we may begin to understand and imitate the formation of the proteins which are vital to us in such an intimate sense.

Biochemistry is making progress on many fronts. The chemistry of muscle becomes more clear. Hormones have been isolated and synthesized. The vitamins, then the enzymes, lead us toward an understanding of catalysis which reaches far beyond combination on a crystal surface. Photosynthesis yields very slowly to attack, but chloroplasts can now be caused to function in vitro; and we may soon be able to isolate chlorophyll itself without altering its form and association in the living cell, surround it with an appropriate set of pigments to interchange the energy of incident photons, and cause it to fix carbon dioxide in a test tube. It is strange that this particular chemical compound, which is central to life on the earth, which appears throughout the plant kingdom in closely allied forms, which evolution provided as the means for seizing and using the sun's energy, resists so long our attempts to watch it work in an artificial environment.

We have long cultivated living tissue in glass bottles; and recently the cultivation of viruses on such tissue has opened up important vistas in the attack on disease. We have proceeded far in the subtle electrochemistry of nerve action. But our distant view of brain action, through encephalography, is very far from providing means for more than a glimmer of understanding of the mechanisms of the brain. Medicine is still largely empirical in spite of scientific progress in biochemistry and physiology; it has new and powerful tools but understands and controls them only vaguely; and its progress toward logical processes, based on sound, far-reaching hypotheses, is slow because of the appalling complexity of its subject matter. Biochemistry is in its infancy—an exceedingly attractive field for men of courage and fertile minds. This is true also of psychology. And where these meet to attempt an attack upon the brain processes of man, there is a situation comparable to that in evolution before Darwin; many of the essential notions have been or are being excavated; but the critical exciting syntheses all still lie ahead.

These are only a few sample areas. Science is expanding exponentially, limited now by the mental capacity it can attract, but threatened also with limitation in other ways, as indeed is all free thought. The evolution of science has some parallels with organic evolution. It is a radiating evolution, producing new species of science almost daily. There is intense specialization to fill niches in the environment. Certain species have specialized to the point where they have lost contact with the main thread—perhaps have lost their capacity for adaptation. Areas have been occupied in which traditional scientific methods really do not apply, where mutation has not yet produced adequate substitutes, and where natural selection acts but lamely.

Civilization generally, science in particular, proceeds because man can store, transmit, and consult the record; because the experience of one generation is available to the next; because an individual can share the knowledge of his neighbor. There has been great progress in transmission, in communication, with telephone, radio, facsimile transmission, television; but this has thus far touched scholarly affairs only lightly. There is progress too in the storing of the record, with microfilm and new methods of printing. But our methods of consulting the record are archaic and essentially unchanged. The library, as we know it, cannot cope with the task before it. Science may become bogged down in its own product, inhibited like a colony of bacteria by its own exudations. There are thousands of journals in physics alone. One of these publishes five thousand pages a year, mathematical, abstruse, difficult. Who can be familiar with it all, and who can find in the great mass in storage the grain of wheat needed for his next step? The pile is mounting daily, science is becoming polyglot, duplication is rife; synthesis, crossing many fields, becomes increasingly difficult and more and more necessary.

As we look over the whole scene of modern science, the impending difficulty is everywhere apparent. We look at any remote, rapidly expanding field, say the chemistry and energetics of photosynthesis; and there are hundreds of able research men and thousands of publications. The key thoughts are necessarily expressed in language which it would take years to master. An individual can now make an advance of such moment that it would have excited the entire intellectual community in the days when science was simple; but the advance becomes known only in an intimate circle and is grossly distorted when it is described outside the circle. The esteem of colleagues, the recognition by men of understanding, which is dear to those whose lives are devoted to unraveling our common mysteries, becomes severely circumscribed. The great awards become artificial and of doubtful value when there are dozens of accomplishments daily, and the truly admirable advances are often beyond the comprehension of laymen. In such a morass how are the great syntheses of the future to be brought to light?

There are a number of things that can be done about it. Aids to man's thinking have proceeded far beyond pencil and paper. Analytical machines are evolving rapidly. Digital machinery, at the moment, holds the center of the stage with analogue machines in the background. Yet one can conceive an analogue machine which could handle the routine of organic chemistry far better than a man can do. It could have a far more extensive and accurate memory. It could manipulate relationships far more rapidly and with greater and more accurate restraints than a human brain. It could even learn by experience if necessary, like Shannon's mechanical mouse, which blunders through a maze by trial and error the first time it is inserted, but the second time proceeds unerringly to the exit, thus showing much better learning capacity than the mouse produced by evolution. Machines for proceeding from an x-ray spectrograph to the parameters of a crystal still need human intervention to supply missing phase relations, but they may be freed of this disability and become powerful instruments indeed. There are rapid selectors, which can examine a thousand items a second and print out the text of the items selected in accordance with a complex code. It is possible, on paper at least, to build a machine which will proceed from item to item by principles of association, as does the brain, without relying on pyramidal indexing. There is no reason why man should not relegate to the machine all those parts of his thought processes which are repetitive or subject to precise formulation. There is every reason why he should do so and should turn over to the machine all similar parts of the job of recording and consulting his scientific record. In fact he must do so if he is to handle at all the mass of data he is creating and proceed into the maze of complexity which every branch of science promises to become in the days just ahead. But the developing of such machines is now everyone's business in general and no one's business in particular. It requires a major effort over many years and great facilities and support. The coding of existing material presents a barrier to progress which has thus far dismayed those who might otherwise have plunged in to attack the difficulty broadly. So we nibble about the edges, and the main central bulky problem remains almost wholly untouched. It is not a job for genius, for pulling rabbits out of hats, but for years of effort by diverse groups that have varied techniques at their finger tips. Of course the problem will ultimately be solved if we proceed down the road of mechanization and do not get involved in atomic war; but science will probably go deeper into the morass of extensive, uncorrelated, essentially unavailable product, before it emerges.

It appears that science needs new methods as it approaches problems which reach beyond the simple relations on which much of its present success has been built. These methods will involve new ways of storing and consulting the record, no doubt. But they will involve also new patterns of collaboration where several highly specialized disciplines, beyond true mastery by any one individual, are essential for full insight. Civilization began when an individual could approach a problem bolstered by the inheritance of a written record and sharing experience with his fellows. We can proceed effectively on many of the paths now open only when we learn to interrelate the thought patterns of allied minds with far more intimacy than is now furnished by books, lectures, or seminars. As this occurs the ways in which a scientist will proceed about his business, the ways in which youth will be trained, the position of science in society, will be altered greatly.

Why do we pursue science at all? What are the motivations of scientists? It is well to examine these from time to time, but especially so as we attempt to consider the trends and the ways in which scientists may be called upon to work together in new relationships.

Much of the motivation is clear and immediate.

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We need not consider applied science, conducted for commercial or military reasons. Nor do we need to consider basic science pursued because it may later contribute to profitable applications. There are more important categories. One is the research aimed at bettering man's lot, without thought of gain: the attack on disease, or ignorance, or overpopulation. Here the immediate objective is clear, though the underlying motivation is usually unexpressed. But there is a category of research that has no relation to material advantage; it is fundamental science, directed merely at the extension of man's understanding of himself or his environment, or at the extension of his ability to understand.

The motivation behind much of this kind of scientific inquiry is, no doubt, mere curiosity—that strange characteristic of man which, more than anything else, has led to his ascendancy on our planet, and which drives him still toward the mastery of what may now seem the unknowable. Joined to curiosity, and responsible for some of the most amazing flights of genius, is the same aesthetic urge that leads to great art and music. This is peculiarly the case with respect to some of the more abstruse developments in the fields of astronomy, physics, and mathematics. And many scientists derive their strongest motivation, in one way or another, from religion and carry on their mission by faith.

The question of motivation has been examined since science began; every mature scientist has answered it for himself long ago and requires no elucidation of it from me. But there is a reason why it should, from time to time, be considered anew. The number of youth entering on a career in science today is great, and the interest of the public at large in the work of scientists has grown enormously. What do we say to the young man who is immersed in science, with his whole life wrapped up in it? The new things that he must master, if he will advance with his fellows beyond superficiality to creative activity in a specialized field, are so numerous and difficult that he has little time to spend on the philosophical thinking of the past. He is prone to acquire his philosophical orientation accidentally or casually from his scientific teachers, and in doing so he may easily be misled. For I fear that some of the things that are told him in this respect by scientists are erroneous, logically unsound; yet they are likely to be accepted by him just because they appear in scientific dress.

Science has been enormously successful in its representation of reality. Many subjects, once thought to be beyond its purview, have finally yielded to its attack. It normally recognizes, as it proceeds, that there are things it will never know, things that lie permanently beyond the weak sense of man, however extended by instruments. Yet its scope is the whole panorama of the physical universe and all physical aspects of organic life on earth; and these vast areas of knowledge, it is confident, will one day be subjected to its dominion. And out of this confidence, too vaguely defined, there sometimes grows a degree of scientific arrogance. Scientists forget momentarily the limits which science initially set for itself.

Let us consider a presentation that is being made today very forcefully and convincingly. There is nothing fundamentally new about it, for the same presentation appears throughout the history of human thought; but it now acquires a completeness and elaboration which is highly attractive to those who think logically, or believe they do. In substance the presentation goes as follows:

We find ourselves in a mechanistic universe, riding on a fragment from a primeval explosion, projected into nothingness, destined to plunge through space for a while, and then to cool to utter inertness. On this fragment evolution has occurred, an entirely mechanistic evolution from the chance appearance of reproducing molecules, through a myriad of species, sorted out by natural selection, to the appearance of man. Now man, the highest animal, is destined to ride for a while and then perish. There may be millions of other fragments, with organic life on them, sentient beings, conscious of their presence in a role not of their own choosing, riding also to their deaths.

We need not quarrel with this presentation so far. Its formulation is one of the tasks of science. In it science confines itself strictly to the things that can be measured and recorded. It carefully skirts all questions that are not answerable by its methodology.

But from this presentation of the mechanistic universe some recent writers have gone on to formulate a code of ethics as though it followed in logical consequence. This code, in summary, is very simple. Man controls his destiny; let him so control it as to build for himself a better life. That is good which leads in this direction. The code is laudable enough as far as it goes; but it is incomplete and without a logical base in the facts from which it purports to be derived. For it is

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based on a tacit assumption that the mechanistic account of the universe that has been constructed within the accepted limitations of science is in fact a complete account, and a proper basis on which to build a complete ethical code. This is to assert that there is no reality beyond those things which we can measure with a rule or time by a clock and that value can be deduced from a statement of fact. But man's motivations emerge from his entire experience. The seat of ethics is in our hearts, not in our minds. Our ignorance is vast. At every turn, as we reach the boundaries beyond which strict definition and logic, measurement and manipulation, cannot be applied, we are confronted with mystery. Our little minds have carved out a region within which science has proved a guide through the murk, leaving blanks and emptiness, but building a consistent conception. In the few thousand years of our existence the logical powers of the mind have accomplished a synthesis in which we can take pride. But to imply that we now grasp the sorry world entire, that we can now draw final conclusions, is to mistake a first step for a journey. We have a useful formulation, within its realm, but have thus far proved little on which to judge our duty or our mission.

Yet there must be motivations for the moment; we cannot wait until our children perhaps lift the edge of the veil a bit, in order to orient our lives today. Thus there is no fault to find with those who go no further than to consider: here we are; let us build a better world—provided this is stated merely as a working formula. Upon such a simple formula, joined with an equally simple definition of what would be a better world, can be erected an acceptable code of ethics. Such a code has been erected by a large portion of those who work in science. It is at times as fine a code as any that has been adhered to by serious men to guide their lives.

Within limits man now controls his destiny. True, the processes of evolution are still effective, and man's control is as yet feeble. True, he can merely deflect a bit the powerful forces of mechanism and chance which rule his life. But his power is growing, and can be consciously enhanced. By this power let us build a world in which men may live happily. Let us conquer disease and banish the causes which distort men's minds. Let us end war and the pressure of population upon the means of existence, which is one of its causes. The construction of an environment in which there is peace and harmony is worthy of our best efforts. It may enable a little child to be happy and healthy and to avoid the mental distortions which produce distress. In it there will be music and art and a flowering of those attributes of the race which somehow transcend the dull problems of food and shelter. In it man may develop his individuality and rise to true dignity. Let us so build that our children may lead better lives. Our code will be a simple one: that is good which leads toward this consummation.

It is dangerous, however, to regard such a code as logically derived from our scientific attainment. The same logic and the same attainment could equally well support a far different conception of what is good. It does support motivations today which are in stark contrast with those by which we wish to live. Logic alone can lead one toward a code which subordinates all means to their end, means of cruelty and deception to an end of regimentation where the free spirit is at the mercy of a communistic state. The urge to serve one's fellow man is not based on any scientific dogma, and the attempt to give it scientific justification involves a dangerous fallacy. The urge is based upon a deep-seated aspiration of the race, which is its only hope.

The simple creed of service set forth above suffices for the day's work for many a scientist. Yet there is joined with it a deep conviction, a faith if you will, which for many a man furnishes motivation and satisfaction, entirely apart from the current struggle. This is the conviction that it is good for man to know, that striving for understanding is his mission. We are embarked upon a great adventure, and it is our privilege to further it. Even though at times the box that is opened be Pandora's, even though there is both good and evil in what we learn, it is our duty and our calling to extend man's grasp of the universe in which he lives, and of himself. By this process, of beginning to understand, we have made such progress as we have. Though the path be thorny, this is still the way in which we should proceed if we would finally emerge from darkness and strike into the light. For who can tell what we may yet learn? Are we now so wise that we can see the picture whole? A million years is a long time, and it was only yesterday that we embarked upon the great adventure. Who are we to conclude that those things which may be today expressed in ergs or quanta encompass all that we shall ever grasp?

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The concrete convictions from experiment have seldom lasted more than a generation or a century. The gap between the now knowable and unknowable is vast, and the borderline may shift in unexpected ways. We may still learn many things, and our immature science is no rock on which to erect a final structure for man's ethical guidance.

Thus, as we build codes, even simple codes for the ordering of the work of the day, we need to supplement and extend, to incorporate the scientific faith that the extension of knowledge is a good in itself. If we build well, our children's children may lead happy lives. That alone, yes, is worthy of our best. They may lead lives of harmony, and mutual respect, and diversity, such as we can only dream of. But they may increase in understanding. They may be wise. Their grasp may include mysteries which now elude us, even some of those which we now believe to be forever beyond our ken. We would build for them. We would build not only so that they may live the good life; not only so that man may develop to the full extent of his organic potentialities; but we would build so that our sons may penetrate the gloom a bit, may increase in wisdom and understanding, and perhaps even begin to realize what the great adventure is all about.

Here is a key to a motivation and code that we can in all honesty place before youth. To those young scientists who derive their motivation from their religion we do not need, as scientists, to speak. To those who have lost this anchor, sometimes through the very intensity of their devotion to science, we would offer a motivation that is worthy of their best efforts. When we lean upon the simple faith that it is man's mission to learn to understand, there is no place for a fatalism, for an urge to live in comfort and enjoy, for tomorrow we die. There is no true logic in codes that would submerge and regiment and destroy man's spirit. We wish to so act that those who follow may be healthy men, unharassed, in decent and dignified relationships, free and individual, and to develop the powers of the mind to the utmost. This is our definition of the "better" though not of the ultimate good, and it is not subject to distortion for the enslavement of man's spirit. The definition does not flow from logic but from faith, even from the simple faith which is exemplified by our own devotion to the advance of science. If we build well our children may indeed think more deeply and more surely.

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