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THE DUTY OF BIOLOGY[1]

IN speaking of the duty of biology, I refer to the services which, as a science, it may reasonably be expected to render to mankind. We must regard the subject pragmatically, and value it for what it is worth. In order to do this, we must first determine what is of service to our species—to us as individuals, or to *Homo sapiens* generally, in the long run and the fullness of time. Contemplate the situation of a human zygote, soon after fertilization, about to float down the stream of time, and ultimately disintegrate, at least in a physical sense, at the age of say eighty-five years. At the very outset, it is closely circumscribed by its heredity, by which we mean the consequences of innumerable past events. It may be a very serious and dreadful matter if some ancestor mated with some one carrying a congenital defect. This lamentable occurrence may date from the time of Julius Caesar, or from last year. It may be a matter for great rejoicing if the various ancestors united high qualities and the newly formed zygote is in possession of the potentiality of genius. So much, then, for the heavy hand of the past, but what of its future? Being human, this zygote is enormously complex and extremely susceptible to various influences. It is subject to the power of choice, compelled to confine itself to the realization of only part of its numerous potentialities. It will react in the most subtle ways to phenomena which might seem to some outside observer of no possible consequence. The more highly it is developed, the more delicate its reactions, like those of the princess in the fairy tale, who was made uncomfortable by a pea under six mattresses. The science of the mind can not keep pace with these events; we classify and define them, but to understand them we should have to solve the puzzle of the flower in the crannied wall.

Evidently, biology has its limitations; but what can it, what should it, do for us? The human machine, like any other, is subject to mechanical laws. As conscious beings, our very bodies are in a manner external and objective, subject to the domination of our will. I once went through an automobile factory and watched the men at work. The power was provided, and the highly complex machines appeared at first to be working quite independently. One could almost imagine that automobiles would continue to

[1] Presidential address, Southwestern Division, American Association for the Advancement of Science, Phoenix, Arizona, February 15, 1926.

be produced indefinitely, if all the working staff went off on a holiday. But closer inspection showed each man watching continuously, and now and then putting his hand on some screw or lever, making all the difference between efficient production and failure. Still more striking was the great sugar factory at San Pedro de Jujuy, in Argentina, last summer. Here again, vast machines seemed to render ridiculous the ant-like creatures hurrying about them. But I was shown a certain process which required accurate judgment and instant action on the part of the operator; and if he failed the whole product was irreparably ruined. The analogy is not overdrawn, the error is doubtless on the side of moderation. In the sugar factory, the machines remain what they are for long periods of time, and very fortunately do not inherit all the defects of those in use a number of years ago. The sugar machinery is capable of being governed in perfectly specific and well-understood ways, but the human machine is influenced in ways we wot not of, and at times when it is not under observation. Who knows accurately what goes on in his own mind, let alone those of others? In short, so difficult is it for us to know what to do with ourselves that we might well ask for a simpler task, had we any option. History is full of records showing how catastrophe followed catastrophe, merely as the result of ignorance. A cynic might plausibly complain that mankind was like a player, compelled to play a game without being told the rules.

Obviously, the rules will not come to us by any simple process of intuition. They must be read in the book of nature, where they have always been waiting for the discerning eye. Many have already been clearly ascertained and ably set forth. This has been done by the informal committee of the scientific men of the world, working through many centuries, but most successfully during the last hundred years. Make a list of the real contributors to scientific knowledge, and it is pitiful to see how few they are. This service, the most important for every state and every individual, has been rendered by a handful of men, usually working under difficulties. Sometimes they were compelled to hide their light under a bushel, sometimes it was summarily extinguished by vandals. Surely mankind has not deserved the services of its benefactors, if we judge by the way it has behaved.

Yet this is by no means the worst of it. Children, old and young, often react to some delicate toy or instrument by smashing it at once. Sometimes they use it to smash other people. So it has happened that gifts of science have been wantonly misused and we sometimes wonder whether our species will not eventually exterminate itself as a result of knowing how. Thus, with enormous increase in the means of production, with facilities of transportation undreamed of a few years ago, with marvelous control over disease, we still have war and greed, to which these great services are actually made to minister.

We must all admit that the remedy for this state of affairs does not lie wholly in the scientific realm. Without a sense of human values, for which mechanistic science has no justification, we can attain no real virtue. Ultimately, all payments have to be made in the bank of consciousness, the operations of which can only be superficially described. Nevertheless, as a horseman desires a good mount, so we desire the means of riding through life without being trampled underfoot. Science, if asked, will provide this mount, at least if given sufficient notice ahead. Yet we, on our part, must learn to ride. Dropping all metaphor, it simply come to this, that scientific research must be promoted on the one hand and scientific education on the other, so that we may become, so far as it serves our purposes, a nation of experts.

Take, first of all, the promotion of scientific research, the enlargement of the boundaries of knowledge. What are we actually doing about it? If you examine a list of those foremost in biological science in America, you find that nearly all are teachers, executives or engaged in the routine of economic work. The output is of course very considerable, and of high quality; yet I believe neither quantity nor quality approach what should be easily possible. For the best results we need intensive, cooperative work, led by a master mind. These conditions have been fulfilled at Columbia University, and the result has been to raise a new structure of biological theory, the ultimate significance of which can hardly be overestimated. It would be absurd to pretend that this performance could be duplicated simply by creating favorable conditions, but it is not absurd to say that such conditions have much to do with the results. The average scientific man, as I know him, lives a fairly easy life, and as a man may fairly be envied. But his attention has to be directed to many things, his time is broken up and he suffers from the same sense of intellectual dissipation or disintegration which affects nearly every one on the campus. For many people this checkered mental life is not altogether a bad thing. Varied experiences, with a considerable proportion of failure, are normal for the young, who are beginning to learn. A good politician or a good college president needs to have a sort of acrobatic mentality, a capacity for being all things to all men at a moment's notice. Such gifts are of a very high order, as exhibited in a Roosevelt; but they do not make a Darwin. It is not a mere coinci-

dence that Darwin and Wallace, the two great prophets of evolution in the last century, were amateurs, outside the professional fold. So also was Herbert Spencer, who, however poorly he may have wrought in certain respects, left an indelible mark on the human mind.

There is no single or certain way to produce the most fruitful scientific research, but we can at least pay attention to the conditions under which it has been accomplished. Certain things appear essential; time—continuous, unbroken time, is assuredly one of them. The material means, such as books and specimens and apparatus, are taken for granted, or should be. Yet they are frequently not available, and in any case only the expert can properly assemble them. The stimulation of kindred spirits, and cooperation in general, are of fundamental importance. We think of Darwin as working alone, but his letters show what he owed to Hooker, Huxley and a host of correspondents. He cared little for public praise or blame, but very much for the critical understanding and appreciation of fellow workers. Read the lives of eminent scientific men, and it is remarkable how these birds of a feather flocked together. Mrs. Darwin, when recently married, may have found it a bit embarrassing to entertain at dinner the greatest botanist and the greatest geologist in Europe, but they were there by natural right. We are reminded of the phenomena of electricity, a spark resulting when two dynamic centers are sufficiently approximated. So it is with men, and if we want to see science prosper in our country, we must reach a certain density of scientific population. It is doubtful whether Shakespeare could have produced his great plays, except in a period of real appreciation for poetry, such as certainly does not exist to-day.

With all these conditions fulfilled, the work may still fail to become fruitful. It has to be recorded and made available or it is sterile. Leonardo da Vinci minutely studied human anatomy, but his incomparably exquisite drawings were not published until 1898, and his manuscript describing them appears to have been lost, though there are many notes. It thus remained for Vesalius to break the tradition of ancient authority, and create a new science of anatomy. Mendel's work on honey bees, which we should now regard as infinitely precious, was lost because after his death an assistant saved only the well-bound books for the convent library, burning the supposedly useless manuscripts. The plants of Captain Cook's first expedition, of which five hundred copper plates were actually engraved, were left unpublished until 1905, when partial publication was secured through the British Museum. By that time, of course, they had been rediscovered and made known by others. The history of science is full of instances in which good work has been done, and has come to little or nothing because of the failure to publish. It may be claimed, of course, that such failures do not matter much in the long run. Where Leonardo failed to publish, Vesalius succeeded. Plants that Banks and Solander did not make known were described by Robert Brown and others. But such arguments lose sight of the influence on contemporary thought, which is in its turn the means of further progress. In other words, if you delay your journey until to-morrow, and still push on with all possible speed, you will always be a day's march behind where you might have been. Another consequence, perhaps more serious, is the influence on the work itself. Who, to-day, will undertake a large monograph, not knowing whether it can ever be published? Who, again, will make his work fully intelligible by giving sufficient detail, when extreme condensation is needed in order to be able to present the most important things? It is quite true that many scientific writings have been made uselessly elaborate, with padding which represented little of value; but it still remains a fact that we are discouraged from presenting subjects in a broad way because of the restrictions on space. To give a concrete example, suppose we are describing a new insect from Arizona. The mere description will take a page or less, and will suffice to make the species "known," as we say. But if we added an account of the place where it was found, a general account of the genus to which it belongs, a discussion of the distribution of that genus, and a statement of the things we still wish to find out, the story might be made readable and interesting. No wonder that taxonomy is sometimes in disrepute, because unintelligible even to most of our colleagues. It is almost as if we used signs for language.

The southwest has largely depended intellectually on other regions. This must always be true in the sense that increasing cooperation makes for world-wide interdependence, no state or nation working in isolation. But in another sense it should not be true, for to attain this wide cooperation each unit must make its own full contribution. Much of our necessary work must be done on the ground; can not be done in museums a thousand miles away. We must interest our people in the advancement of science, of the science that lies close at hand, at our very doorsteps. If it is suitably presented, it will not seem so dull or incapable of being understood. We should be able to do our own work, and publish our results, or at least provide the means to have them published. We do not lack the funds, had we the will and interest. I suppose it is true that daily, in the United States, we waste enough to publish all the scientific work of a year.

The other side of our problem, that of general education in science, is no less beset with difficulties; but they are equally, I believe, capable of being met. In spite of all our schools and colleges, we have not yet created what might be called a scientific atmosphere. It is not altogether the fault of the public. The teaching profession itself has been and is in a state of perplexity regarding these matters, and sorely in want of an intelligent and well-supported program. Within the ranks of teachers I find two groups whose views seem to me harmful, having regard for the character of our civilization at the present time. One group consists of those who still cling to the old idea that science is only for the elect, and that a little knowledge is a dangerous thing. Such men are keen to train experts, and often render the highest services in this manner, but they do not desire to see the multitude scientifically trained. The other group includes those who abhor the technical or difficult side of science, and wish it made simple and easy. They think the aroma of science is enough, without the substance. These also often render good service by bringing simple ideas and conceptions to those able to assimilate them, as is sometimes done so efficiently in moving pictures. We should, then, have no quarrel with either group, were it not that the result of their combined efforts is to deprive the people of substantial scientific training. General science, given without laboratories by a teacher who is not expert in any particular branch, may have its uses at a particular stage in education. It is, however, no substitute for biology, chemistry and physics in the senior high school, with competent teachers and laboratory facilities. It is certainly true that scientific courses in high school and college have been criticizable for content and methods of presentation. The same criticisms are applicable to courses in mathematics, and for that matter to the old classical courses of the days when Latin and Greek were the backbone of the curriculum. I have not forgotten the absurdity of trying to memorize the list of kings of Israel or recite page after page of Ovid. Yet one has only to look at the now current text-books of biology to see how greatly the teaching of this subject has been reformed. It has assumed new and varied aspects, relating itself to innumerable human interests. In the hands of good teachers it is competent to enlighten the world and make the higher civilization a practical thing. It will enable us to see where we were blind, to sense the trends of progress and intelligently choose our leaders. Without it, we are abandoned to superstition, quackery and disaster, for nature gives no quarter to those who will not or can not play her game. Let us then resist to the uttermost those who would succumb to the great modern illusion, which teaches that we may have pictures without knowing how to draw, music without ability to play, science with only the simple conceptions of a child. This is the voice of barbarism, calling from the darkness of the past. Certainly, we must concentrate on the arts of presentation, and remember that learning does not cease on leaving school. Many matters, now regarded as hopelessly abstruse, may be made intelligible to the majority. Science must seek the aid of literature, even of poetry and the drama. Look at the poetry in the current magazines. Aside from its technical qualities, concerning which much might be said, how futile nine tenths of it is! It offers us for the most part the vapid sentiments of egotists, who are incapable of any higher emotion. Yet poetry has been and sometimes still is the vehicle for the expression of human thought in its highest forms. Let the dynamic ideas of science and their application to our affairs supply the content for new and virile verse, which may stir the minds and hearts of thousands! Can we, from out of our multitudes of ardent young folks, find a new Tennyson to do this great thing?

From these exalted conceptions, it seems ridiculous to pass to the question of compilations and indices; yet these are just as essential in their way. Even poems have to be classified and indexed, if we are to find them when wanted. When we speak of scientific research, we think of enlarging the boundaries of knowledge, but much of the energy of scientific men is necessarily spent in consolidating the gains already made. The Germans do this kind of work very well, and I, for one, am constantly indebted to their painstaking compilations. America, on the whole, is seriously behind in these matters. We have no general account of the fauna of the United States, not even a list of the species. In numerous groups, it is easier for me to determine a species from India, using the great Fauna of British India, than one from the Rocky Mountains. We have published many fine monographs, but they are for the most part expensive or difficult to obtain, or else are so purely technical that the beginner can not use them successfully. We of the west should shoulder our own burden, and prepare a really intelligible account of the natural resources of our region. This could not be done all at once, but it could be planned for, and developed by degrees, like a modern city. It might begin with a simple check-list, a sort of census of what was known, reduced to its lowest terms. Then, as workers were found, the flesh could gradually be put on these dry bones, and the subject made alive.[2] Such an undertaking would, from its nature, never be

[2] Warren's "Mammals of Colorado," written at Colorado Springs, is a fine example of this type of work. The author had to subsidize the publication.

complete. It is fortunate that it should be so, for the work itself is most worth-while, and through it we should attain, not merely scientific ends, but the moral virtues of fellowship and intelligent cooperation. As for the expense, it ought not to be necessary to mention such a thing.

I referred just now to the resources of the country, and I suppose some of you are wondering just what those include. Is our great undertaking to include simply the sources of food or shelter or clothing? Or if we include the flowers, is it only because they can be eaten by cows, or because innocent people will sometimes buy them, and so give them commercial status? I do not so understand it. We live in a great and wonderful environment, to which we may react in a thousand ways. Broadly speaking, happiness comes through the harmonious exercise of our faculties. To be blind where we might see, callous where we might feel, dumb where we might speak—these are the great futilities, in the presence of which material wealth is of small account. Thus we must hold that our resources are only limited to those things which we can appreciate with our senses, and get some good by so doing. Wealth of this kind is so abundant that there is more than enough for all. No one can use more than a small part of it, but many minds and hearts, with a common purpose, may approach a grand synthesis which some genius will clarify and define. This is the manner of intellectual progress.

In this country of ours we are facing a somewhat new situation. Thanks to science, material wealth has increased enormously. With the spread of democratic ideals, life has become easier, the hours of labor shorter. People have time and money as they never had before. What are they doing with them? We have only to look around to see resources wasted, and time—the precious hours and minutes of human life—squandered on inanities. We do know how to work, the whole world admits that, but we do not know how to play. Now with the pressure of a complicated civilization and the dominance of machinery, our working hours are more and more standardized as to their content and the manner of our operations. We are necessarily slaves to the system or to the machine. This is no great evil, so long as it occupies only part of our time, and we have still enough in which to dream, and invent, and discover. But if the free time, the so-called leisure time, is deprived of worthy activities, not only is life reduced to its lowest terms, but the very springs of progress are dried up. Thus the appreciation of nature, including human nature, becomes a high social duty, through which personal happiness and national progress may be attained.

And, after all, even in those dark valleys of sorrow and loneliness which we all have to cross, there comes the sense of the unity and permanence of this wonderful universe, in which loss is followed by gain, apparent death by resurrection; and we, atoms that we are, are partners in the firm which shall never be dissolved or go into bankruptcy. Vital activity is our business, and through it, in all its varied forms, we may realize the purpose of existence. Putting the thought in verse, we may perhaps express ourselves in this wise:

The world is full of sorrow, and sad the heart of man,
Put on the bright and merry tune, and dance it if you can,
And let it be a token, that in ages yet to be
The flowers will blossom in the fields, the glory of the sea
Will never fade or pass away, nor will the changing sky
Its lovely pageant fail to show, as hours of daylight die.

So banish man-made ugliness,
Let vulgar notions fade,
And learn to know the loveliness
Of that which heaven made!

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NOTES ON THE AIRY OR "ROOTS OF MOUNTAINS" THEORY

THE Pratt theory of isostasy calls for a uniform thickness of the crust or, at least, it is supposed that the crust extends to a uniform depth below sea level.

The Airy theory, on the other hand, postulates a varying thickness. This is practically identical with what is generally called the "Roots of Mountains" theory and we shall therefore speak of the two as the "Roots" theory.

In the Pratt theory the major, and perhaps other, changes in elevation must be due to changes in the density of the materials of the crust below the affected surface. The changes in density may be uniform throughout the crust, they may be greater at one depth than at others, or they may affect only a part of the crust. Although we may prove the Pratt idea by geodetic and other evidence which might be available, it is possible that we shall never be able to determine the exact distribution, with the depth, of the changes in density resulting in the formation of a mountain system or a synclinorium.

Isostasy seems to have been proved. Just how the densities of the crust are arranged to give the equilibrium, found to exist, and how the equilibrium is maintained are interesting problems still unsolved.

In this short paper let us lay aside the Pratt idea and give our attention only to the Airy or Roots theory. I am assuming the rôle of an advocate of