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Biology in the Atomic Age

FIRST I WISH to bring the greetings from my own university, now a bit snowbound, but I trust still active. There are perhaps some creaks and groans because we have celebrated our 300th birthday, and I am delighted to see you so active, so eager, on your 100th birthday.

I am very glad to have this opportunity to talk with you about biology, taking it in its broad sense in the atomic age, because Iowa State College played a very large part in bringing about the atomic age. I recall the small building, now torn down, where the uranium for the first atomic reaction on a large scale was manufactured. It was the sole source of purified uranium for a considerable period. One of the things the last war brought home was that the advances in science are made not in the arsenals of the nations, but rather in the universities of the nations. For the technical advances made acute in the framework of war, one needs the results of the skilled, patient, careful exploration of the unknown. That occurs primarily in the universities. As one sees the changing pattern of the atomic age, one is struck by the rapidity of change. At Hiroshima and Nagasaki it was demonstrated clearly that it was 3,000 times as cheap and easy to destroy as to build — reversing a trend in warfare that had been steadily reaching a more and more costly peak from the days the first two cave men decided to argue over who would get the larger share of the animal that they were carving up.

With this major break-through, which came about by a series of very rapid steps, we were precipitated into a period where the advancement of science became almost incredible. Even the imagination of Jules Verne had not adequately visualized satellites circling about our earth and giving us information as to the conditions of space, making it possible for us to talk seriously about problems of space travel.

Just as it is very difficult to see where the next advance will come, one recalls that the crude experiments of Lord Rutherford less than 40 years ago have led to the transmutation of elements, incidentally just the reverse of the goal of alchemists in the Middle Ages. Instead of transmuting mercury into gold, they transmuted a few of the atoms of gold into mercury, but opened up thereby the chance for the development of the whole field of understanding of the structure of the atom and the ways of utilizing the energy of the atom.

Biology in the atomic age is perhaps distinguished by this matter of having extraordinarily effective tools of amazing accuracy and speed. It is also faced with problems that are brought about by our changing environment — chiefly environmental radiation. These two factors, perhaps more than any other, affected the course of research in biology since the atom has become readily available and since man has been able, on a large scale, to bring about changes in his environment. Let's take the first. The ability to distinguish and trace quickly individual atoms has made possible unravelling skeins of intermediate metabolism, has even made possible the recognition of intermediary compounds that we didn't know existed because of the fact that they had relatively short lives in the biological change and because they were difficult of analysis. The tracer atom made it possible to recognize these with a rapidity that had never happened before. I recall in my own laboratory how proud I was when we were able to make a determination of phosphorus in microgram quantities. This was a major achievement and took three to four days' work. Now, with radioactive phosphorus, one is concerned not with microgram quantities but with millionths of microgram quantities, and the determination is down to fifteen or twenty minutes' time.

For the first time, then, we have a way of very rapidly learning what is going on — and not only learning what is going on by breaking down and analyzing substances, but learning what is doing on while those substances are still in their original and active form. The speed with which many biological syntheses are accomplished — even the most complex such as protein synthesis — has proved surprisingly fast, a matter of minutes in many instances. I am sure that Dr. Spedding has been somewhat envious, in his field, of what bacteria or protozoa or more complex organisms can do. This extraordinary ability of biological processes to work with great rapidity, even when very complex, had been suspected but not fully appreciated until the pathways could be followed with the atom.

It is interesting to realize that these atomic tools which are now quite a matter of course in many laboratories are nonetheless relatively new. The first distribution of isotopes on any reasonable scale came about in 1946. Now thousands of shipments are made annually from various laboratories, and work is going on with them in all parts of the world — in India, South Africa, Germany, Russia, as well as in the United States. And a very large share of this world-wide revolution in biologic thought and biologic approach owes its very existence to the pioneer work that was done by Dr. Spedding and his group here at Iowa State College.

One of the things that we have been able to do by virtue of having these various tools available in biology is to understand how molecules combine and separate, recombining within our own bodies as well as within the plants and animals on whose lives our own are so dependent. We've learned that even structures that we thought of as comparatively stable, such as teeth and bones, are unstable to an extraordinary degree and take a significant part in the daily metabolic activity of the body.

One of the instances where time is also brought into play in relation to biology in a rather interesting way is through the use of carbon 14. Dr. Libby's observations permitted analysis of small amounts of carbon 14 and brought out the fact that any biologic matter, while it is alive, is in equilibrium with carbon 14 in its environment. The fact that it ceases to be in equilibrium with the carbon 14 of its environment when it dies has been an extraordinary tool in determining the age of things under 25,000 or 30,000 years. For example, it has been possible to date with accuracy the grass sandals that were found in the caves of Oregon and were made about 14,000 years ago. It has been possible to check on the accuracy of the tree calendar that tells us much about the ecology of the southwestern portion of our country, in particular in the past, and throws light on the present trends. Sometimes this has proved disconcerting. For example, on checking the age of one of the mummies in the museum at the University of Chicago, it was found that a ringer had been worked in which was only 125 years old instead of belonging in the dynasty of the Pharaohs.

Another use of time has been to go back to the other scale — the very long-lived isotopes such as uranium — where one thinks in hundreds of thousands of years. And this has enabled us to get a much clearer understanding of geological time. One of the things that has happened with the use of the tracer atom to open up these various biological processes is the possibility of understanding much more clearly what goes on in the aging process of various metabolic diseases. When I first became interested in diabetes as a disease process, for example, it was necessary to measure the amount of sugar, protein, or fat that went into the patient, to measure the amount of oxygen that he consumed, the amount of sugar that he spilled in his urine, in order to estimate what was happening. We got about as sound an idea as one gets from watching the trucks go into a factory and the product that comes out of the factory. But just as a while ago the Coca-Cola Company and others began to put plate glass windows in their bottling works so that you could see what was really going on, so the tracer atom has enabled us to open up and follow the biological processes and to determine just how the metabolism was carried on, just where it was going wrong, and to learn much more accurately what to do about it.

In addition to learning a great deal about the normal functioning of man and animals, numerous pathways have been opened up for us in the diagnostic field. We can detect changes in the thyroid gland, for example, in man and animals, by the use of radioactive iodine that we never could have detected in any other way. And there are many other advances in human medicine and veterinary medicine, thanks to the availability of these materials.

The use of the tracer atoms, of course, is not limited to an individual man or plant or animal, but can be used to a tremendous degree in ecologic studies or in quickly checking the distribution of a fungicide or insecticide. And on an even larger scale one finds that oceanographers can learn a great deal about the life of plankton, a great deal about the food change, in relation to fishes of importance, a great deal about the currents by virtue of having large amounts of waste products or radioactive isotopes with which to trace. Probably more advancement has been made in the field of meteorology as a result of radioactive fallout from atomic tests than could have been brought about in any other way. They had one crude tracer, to be sure, when Mt. Krakatao exploded in the 1880's and put millions of tons of dust in the atmosphere. But this was difficult to trace with accuracy, and only the brilliant red sunsets of some Remington paintings are left as a reminder of this period. There is some information that was gained in the days of the Dust Bowl when the particles of known soil character could be traced for long distances. Sands of the Sahara have been tracked up into Turkey and the Crimea. But the motion of major air masses and the understanding of these really came about only when we had great masses of radioisotopes in the form of ashes of atomic explosions available to trace them.

There has been one area of disappointment thus far in the use of radioactive materials in biology and medicine.

We have not found any striking cures. There is nothing that corresponds to the discovery of the sulfa drugs or the antibiotics in the field of therapy. And while the field is yet young, it still looks as though we would make a number of significant but relatively minor advances. We have to look more to the research potentials of the radioisotopes than to the actual utilization of them in the treatment of disease. And it appears the radioactive isotope is at its best as a research or a diagnostic rather than a therapeutic tool.

The other side of the coin is the problem of potential changes that may be brought about in our environment by the atomic age. And these are already manifold. Radioactive wastes in fallout from atomic explosions are a factor in this. Sometimes the changes are simply related to changes not radioactive in themselves but brought about by radioactivity. For example, at the Hanford Works of the Atomic Energy Commission, our major problem is not in relation to the radioactivity and the wastes from the Hanford Works, but rather in the fact that in cooling the atomic piles we raise the temperature of the Columbia River enough so that it is just borderline for the salmon runs there. And in order to preserve the salmon industry in that river it has been necessary to take extraordinary precautions with regard to temperature control. One of the problems that we have close to home is that the Yankee Atomic Company is putting a reactor in western Massachusetts at the headwaters of one of the best trout streams of the area. This stream will be warmed up by some 10 degrees by the operation of the plant, and there is a question as to whether the present trout will do as well as they have in the past.

So there is a considerable range of these problems, not only atomic but others as well. There is the problem of waste disposal that needs to be thought of, because in any atomic reaction there are ashes just as there are the ashes of an oxidizing reaction of coal and wood. And these ashes are radioactive, hence a problem. In a country as vast as ours, with the broad expanses of barren areas, waste disposal does not provide a problem for us. It is more of a problem in such thickly settled areas with limited expanse as the United Kingdom, for example.

At the present time all foreseeable atomic wastes can be handled in this country either by burial or by safe sea disposal. Of course, the ideal answer to waste disposal is to do just what the packers have been able to do with hogs, to have the waste become of value so it ceases to exist as a waste problem. This can very likely be brought about in certain of the components of atomic wastes, perhaps not in relation to others. Still another environmental factor is that with the increased use of reactors — the increased transportation of materials for reactors or coming from reactors — the hazards of accidents also must be weighed. In the reactor the fuel elements are so arranged that even with a very serious accident an atomic explosion is virtually impossible. I asked a very competent theoretical physicist to give me a guess on this, and he said about one chance in three hundred billion. And that is on the order of chance of another star messing up the solar system.

On the other hand, there are other potential hazards not so serious but nonetheless annoying, such as the accident in the United Kingdom which you may have read about where I^{131} escaped from the accidental burning of fuel elements in the pile. Fortunately, because they were alert to the problem, there was no injury to man. But as the material settled out (and iodine changes very easily from a gas to a solid), it settled out on the forage pastures down wind. And some of it was carried not only through England but even to the Continent. Its path was checked as far as the Iron Curtain.

Closer by, there was enough in the pasture so that the cows grazing there picked up the radioactive iodine, incorporated it into their milk, and excreted it in the milk. As the result of this, some of the milk from adjacent milksheds had to be condemned, more for public relations reasons than any other until the radioactivity had lessened with the passage of time. It would have been perfectly feasible to have held the material for a few half-lives and soon it would have become completely harmless, but they were a little afraid of the public relations effect of this. It is like a number of things we know are perfectly safe but not always appealing from another sense. Once something has been bad we are very apt to continue to assume it to be bad.

Another thing that is changing in our environment with regard to radioactivity is the fallout from atomic weapon tests. As yet this is relatively insignificant although its effect is world-wide to an extent that is not generally appreciated. If one takes snow from the antarctic ice cap and melts it, one finds radioactive strontium. And because of its somewhat longer half-life, it is regarded as a chief danger and we check for this more carefully than for other elements. To give you a rough idea of how carefully this checking has been done from various portions of the world, something like over a half million analyses have been made. So we do quite well on the distribution of radioactive fallout, the amount of the chemical concentration, and the radioactivity. There is rather more concentratation in our latitude between 30 and 50 degrees north than elsewhere because this happens to be along the wind path that relates to both our tests and the

Russian tests. The southern latitudes have somewhat less. There has been gradual stratospheric diffusion from the tests in the northern hemisphere and also some supply from the tests of the United Kingdom which are carried on near Australia, as you know.

Now since this radioactive strontium can exchange with calcium and bone and acts just like calcium, and since even at low levels in mice it may cause the development of bone tumors or possibly leukemia by irradiating the bone, a tremendous amount of research has been carried out. And we have a number of analyses of this level in human bones. The evidence indicates that the uptake in human bones is not at a dangerous level and, in fact, is well under the dose regarded as acceptable for occupational exposures. It is of interest to stop and think that every one of us undoubtedly has a number of atoms of radioactive strontium incorporated at the present time, and then to think that this material could not exist until the atomic age occurred. This is fairly new material and yet every person, every animal on the face of the earth as far as we know, probably has at least some radioactive strontium in it. It gives an indication of how environment can be changed in these days. The radiation thus received from radioactive fallout is about one-fiftieth of the amount the average adult in this country has received from medical and public health applications, that is, chest surveys, the use of X-rays, and is much less less significant in increasing one's exposure to radiation than would be moving from Ames to Denver or Salt Lake City. Nonetheless, since it is a widespread man-made source, the level of environmental radiation has been, and will continue to have to be, extensively studied. As a matter of fact, we know a great deal more about the potential danger from radioactivity than we do about the potential danger from automobile exhaust fumes.

One of the most amusing things that I have seen recently was a parody of one of Linus Pauling's articles on the hazards of radiation adapted to the use of coal. The parody pointed out that this was an extraordinarily dangerous substance because when ignited it could not always be controlled and there would be great destruction of property and lives from fire; there would be carbon monoxide gas produced; there would be any number of chemicals produced; it was very hard to handle because it could heat things up to hundreds or even up to about one thousand degrees centigrade, and this was going to be rough on metals that it came in contact with. One wondered if all these things had been said and widely debated publicly when coal first began to be mined, that perhaps there might not have been some degree of public anxiety as there is today in regard to use of atomic energy.

One of the reasons that we need to study radiation very carefully in our environment is that radiation is an important source of mutations. It is assumed by the geneticists that a fraction, or some say almost all, of the mutations now present in the human race have been brought about by the action of radiation from the natural background — the cosmic radiation, the radiation from the radioactive potassium and radium in our own bodies, the radium that is frequently found in drinking water, and so on. And it is quite possible that these have played a significant part in bringing about the mutations that have gradually led man from his primitive state, by a process of elimination of the unfit or unadaptable, up to the present time.

One of the things that particularly concerns us today is that the process of selection is not working as effectively as it has in the past. When the time was that the patient who developed diabetes on the basis of heredity died before having children, there wasn't a major heredity problem. But with better treatment of diabetics we are keeping the genes of those individuals who are carriers active in the pool of the race and hence have the likelihood of many more diabetics in future generations, and so it goes.

The geneticists say we should go very slowly and carefully with anything that is apt to bring about radiation mutation. This is seen perhaps most vividly in contrasting what one knows about obtaining better breeds of plants by radiation and about obtaining better breeds of animals. The plant geneticist can irradiate tremendous numbers of seeds and broadcast them over acres and then can watch for those plants that are doing the things he would like to have them do. As a crude example of this, a number of years ago about half a bushel of peanuts was shoveled into the atomic reactor at Oak Ridge and these were heavily irradiated. Then they were planted in North Carolina. Some of them failed to come up, some of them were pretty unhappy, spindly plants. Others proved to have increased yields, or produced a much larger peanut. Others were resistant to blight, others resistant to drouth, and by selection from these it was possible to obtain improvement in the type of peanuts and rapidly get this up to a level where it would have commercial importance. Now with animals one can't do that. You can't handle as large a number. Imagine trying to irradiate cattle at random and breeding a few million cattle, trying to pick out the good ones that you wanted. It just isn't a practical approach. So, in general, for the plant geneticists, radiation is a useful and practical tool. For the animal geneticists and human geneticists we have to assume that in general, mutations prove to be bad rather than good.

Perhaps the most valuable aspect of atomic energy in the field of genetics has been entirely a side product — the stimulation of large-scale genetic work — research that would not otherwise have been carried out. We have, right here at Iowa State under Dr. Gowen, a very important project in genetics related to the radiation problem. We have at Oak Ridge now, I think, about a quarter of a million mice that have been involved in the experiments on genetics there. We have experiments on dogs going on in different parts of the country. Similar experiments are being carried on in different parts of the world and must be carried on so that we will know what the problems of good and bad are. We are somewhat in the situation that Adam and Eve were in. We have the apple, and the question is how far to bite into it in relation to the good or evil that it may bring.

Now, in the course of the discussion of this problem of our changing environment incident to the utilization of atomic energy, some very useful facts have been presented, some things that purport to be facts but are not, and a great many emotional viewpoints. You probably have noticed in any argument that the further one gets away from the fact, the warmer the argument becomes, and this is true in this field as well as in others. One of the very fortunate things is that we have a period of time in which we can choose what we should do in order to find out the good things that are available for us and to find out what the hazards are and how we may control them.

One point that is of importance to us is to know what the social burden of these environmental changes may be. Is it going to be an overwhelming one? Is it going to be a significant one? Mutations cannot be predicted with accuracy as to number or as to type. But we can make a rough estimate of the probable number of mutations in man at the present time. And we can make the assumption that doubling that number would not place too serious a social burden on the earth's population. This amount of radiation that would double mutations has been called the "doubling dose" and is regarded as an amount of radiation which, in the light of present knowledge, man should not exceed. The value of this doubling dose is a matter of speculation. The estimates run from very low to as high as 400r, with 10r as a probable low limit and 30 to 50r as the rather likely level.

Now what is an r? It is an arbitrary unit of radiation. It is an abbreviation for roentgen. My wrist watch has a radioactive dial. And that radioactive dial is constantly irradiating the skin of my wrist while I wear it. And in the average time that I wear it, approximately 16 hours a day, the skin underneath gets the same permissible dose that would be safe to give my entire body. That is three-tenths of a roentgen for a week. This is a safe level of radiation as far as systemic effects are concerned; it is a level of radiation that might have some genetic effects.

However, there is another point that we must remember in relation to the genetic effects. This is that the effects may be apparent in the first or the second generation, but that many generations must pass before equilibrium is reached. This is fortunate with man because the present levels of radiation, due either to weapon testing or industrial utilization of atomic energy, are very low, and therefore we have time to sample the good and evil potentials of atomic energy — to choose wisely, I hope, between them.