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Biology at the Frontier

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Alexander the Great after all his conquests is said to have sighed because there were no more worlds to conquer. Yet as he stood on the banks of the Jaxartes he could hardly have failed to see the vast stretches of untamed territory lying before him, even if he had no inkling of the unknown new world across the seas. An Alexander the Great of Victorian Science Lord Kelvin took his stand on a metaphysical Indus and boasted that within a short time the whole world of nature would be subjugated. There would be no frontiers left to science. Seldom was complacency so quickly deflated. In three successive years the discovery of X-rays, of radioactivity and of the electron shattered the Victorian concept of the world as a vast three dimensional billiard table with sharp boundaries on which scientists played a mammoth game of snooker.

More recently the molecular biologist Gunther Stent wrote a book called "The Coming of the Golden Age", the theme of which was the end of the sciences. Science will have delivered the goods, hence the Golden Age. He elaborated his thesis further in "Paradoxes of Progress", 1978, and spoke to us about that in this very lecture theatre a few years ago. There would soon be no frontiers left for science. When I was completing my undergraduate career in the University of Melbourne and was thinking of the possibilities of a research career, I remember bemoaning with a fellow student that all the major discoveries had been made and certainly the easy ones. I have learnt a lot since then.

Indeed one of the things I have learnt I would put into the principle – while knowledge increases arithmetically, ignorance increases geometrically. In other words, every advance in knowledge creates more problems than it solves. There is never likely to come a time when there will be no more intellectual worlds to conquer. The contemporary scientist finds himself more in sympathy with Sir Isaac Newton's view of his own achievements: the great ocean of truth still lies all undiscovered before us. The scientist is like someone perpetually cleaning out a cluttered basement. No sooner is the basement outline seen when someone finds a cleverly hidden trapdoor leading to a vast subbasement. In scientific research there is one general law – the unexpected always happens. So we can never really predict but we can anticipate new frontiers at each step of really probing research.

The biological sciences are undergoing a transformation which has only just begun but which promises to be so revolutionary in opening up new frontiers that professors of biology who will

take their place in this University in future decades will bear little resemblance to those of past decades, that is unless the University of Sydney gets stuck in a rut which heaven forbid. Even I bore little resemblance to any of my forebears in the Challis Chair of Biology. The contrast will be even greater in the future. One transformation is well under way. The other has hardly begun. The first I shall call the concept of levels of biology. The second is the holistic concept of the unity of all life.

Biological Levels

When I first came to this University, biology was subdivided into botany, zoology, genetics, microbiology and so on. It was a simple taxonomic breakdown. And it didn't work, at least from the time when biologists came to realize that the same processes went on in animals as in plants as in microorganisms. Their biochemistry is extraordinarily similar. So is their genetics. Genetics started with plants, continued with fruit flies and is now largely a study of microorganisms. It became pretty clear that both research and teaching in biology was not served adequately any more by persisting with the old subdivisions of biology. The alternative was to think of biology in terms of levels of organisation. There are four: molecular, cellular, the whole organism and the population. Some might want to add a fifth they would call ecosystems, i.e. the organism and its environment. I reject that as totally artificial because at every level the entity, be it molecule or cell or tree. can only properly be conceived as having an environment. So I say no more about it.

The transformation of biology in terms of levels has primarily taken place at the two ends, the molecular end and the population end, and that is where the growing points are. The greatest conceptual advance at the molecular level is, I venture to say, the concept of molecular ecology, a phrase invented by Paul Weiss, a developmental biologist. Just as the Newtonian concept of the universe as a billiard ball universe has given way to a much more ecological view of matter, so too the transformation is taking place in molecular biology. No longer are genes particles on chromosomes. No longer do we talk about particulate inheritance. What we call genes are what they are by virtue of their relation to their environment. What a gene can do depends upon neighbouring genes on the same and other chromosomes, and on the other environments of the cell in which the genes find themselves. This is an ecological concept. You cannot simply say that gene x does this. What it is and what it does depends upon the environment. The part of the DNA that is expressed at any time depends on the environment, and that same environment keeps other parts of the DNA suppressed. Nothing is completely determined. Indeed the concept of degrees of freedom becomes quite relevant at this level of biology. If I were to go on with this story, as it can now be told in some detail, at least for some bacteria, I think I could persuade you that we might well talk about the life of the DNA molecule. Things go on at that level which we never dreamed of, and which we thought belonged only to cells and higher organisms. The American biologist, Lewis Thomas wrote a book, "The Lives of the Cell"; someone might well write a book entitled "The Lives of the DNA Molecules". Biology has advanced at the molecular level mainly so far by studying microorganisms, and particularly one, *Escherichia coli*. But as we seek to understand and control other organisms besides microorganisms, future thrusts are moving fast in that direction. And when you come to think of genetic engineering in which genes from one organism are planted into another one as far apart as a human and a bacterium, then you realize that it too is at centre ecological. We are giving genes new homes, and as yet we are uncertain as to how the new environment will influence all their activities, and for that matter the activities of the genes in the recipient organism.

I said that the transformation of biology is taking place primarily at the level of the molecule and secondly of the population. Population in this context means populations of organisms such as mosquitoes or people. The principle of population ecology is that organisms can only be

properly understood as we study them in relation to the numbers and kinds of their own species around and the numbers and kinds of other species in their environment. Most of the advances in population ecology have come from studies of organisms that we want to make rarer because they are pests, or that we want to make more common because of their usefulness to humans. And more recently there is the added component of threat to all life of changes in the habitats of the earth due to human activity and changes in the atmosphere surrounding the earth. A proper study of human ecology would include all those organisms on which human life is dependent, not only those that serve as food but those that maintain what we call the life-support systems. These are the organisms that contribute to the stability of the composition of the atmosphere and the degradation of wastes on land and sea. Every year sees the disappearance of more and more species from this planet and yet we cannot predict the consequences of the extinction of a given species any more than an airline passenger can assess the possible consequences of the loss of a single rivet from the wing of a plane in which he or she is travelling. So concerned is Paul Ehrlich that in his book, "Extinction" he argues for the saving of all species from henceforth as part of the lifesaving of human life. So I see the studies of population ecology extending to many more species than we have at present studied, and this is a vast programme. The European rabbit in Australia is one of the best studied animals from an ecological point of view. It involved the research of many full time biologists for close on two decades and still there is more to do. We can expect to know little about the population ecology of any species unless the study covers at least a decade and involves many workers. To date these sorts of resources have only been available for work on species of well established economic importance such as the rabbit in Australia. A major problem in this work is that both the time needed and the resources needed are more readily available in research institutes than in universities. Yet the universities need to become much stronger in this field of work. The quality of the teaching of a university is related to the quality of the research in that same institution, so it is important that both go together. I cannot see that happening in Australia to the extent needed unless more research institutes are established in the universities themselves. There are already some good examples. The Waite Agricultural Research Institute of the University of Adelaide is outstanding in this respect as is the Walter and Eliza Hall Institute associated with the University of Melbourne. To set up biological research institutes with adequate staff and buildings is now an expensive operation far beyond the normal resources of the University of Sydney. The University of California at Berkeley has recently been allocated $41 million of state funds for a building alone for the Life Sciences. A new Institute for Basic Research in the Life Sciences has recently been established in Odawara City some 80 km from Tokyo. It has an initial outlay of $21 million with 50 scientists and 50 support staff. It is not in a university and belongs to Meija Milk Products. In 1984 alone six new research institutes in the Life Sciences have been opened in Japan all of them outside universities. Barriers between universities and industry are said to be just too high for effective research cooperation in Japan, so there has been no accompanying boom in research in Japanese universities. A major problem for the future of the life science in Australia will be whether the universities will continue to fall behind Commonwealth Government Research institutes in facilities for research. It is these rather than private industry which do much of our basic research. I find it sad that cooperative research between universities and CSIRO within the University campus is less now than it used to be. In the past that was one way of sharing the wealth available for research.

A New Holistic Emphasis in Biology

Here we come to the most difficult frontier of all to explore. The physicist, Paul Davies, in his book "Superforce: the search for a grand unified theory of Nature" (1984), said , "Like many compelling images it may turn out be a mirage, but for the first time in the history of science we can form a conception of what a complete scientific theory of the world will look like". In this

exploration the physicists are far ahead of the biologists and the danger is that the new complete scientific theory of the world will have no contribution from biology. If that is so, it cannot be a complete theory of the world. The time is ripe for biologists to adventure into quite uncertain seas of unknown depths to seek a unified theory of nature. It needs tremendous imagination. I remember the biologist C.H. Waddington saying to me some years ago that in quantum physics you are not likely to make a contribution unless you have outrageous ideas, to think thoughts that no one has thought before. Waddington was one of the few biologists of his generation who attempted to do this in biology. Another great biologist of our time J.B.S. Haldane said, "Now, my suspicion is that the universe is not only queerer than we suppose, but queerer than we can suppose". (J.B.S. Haldane, 1927, p.286). His distinguished father, J.S. Haldane, also a biologist went further in his Donnellan Lectures, "The Philosophical Basis of Biology" when he concluded "Personality is the great central fact of the universe. This world, with all that lives in it, is a spiritual world." And that is why he made this seminal prediction about the future of science, "That a meeting-place between biology and physical science may at some time be found there is no reason to doubting. But we may confidently predict that if that meeting-place be found, and one of the two sciences is swallowed up, that one will not be biology." (A. Hardy, 1965). And again his son J.B.S. Haldane said, "And though today the theoretical physicist is and must be the principal type of world builder, the biologist will one day come into his own in this respect." (J.B.S. Haldane, 1927, p.281). The similarity between father and son was a source of some confusion. When J.B.S. Haldane was asked on one occasion was he related to J.S. Haldane, he replied, "that depends upon whether identity is a relationship."

Who are the biologists in our time who have attempted exploration in that direction? There are few of whom the following are outstanding: C.H. Waddington, Bernard Rensch, Theodosius Dobzhansky, Sewall Wright and W.H. Thorpe, and I am happy to be able to include one Australian, indeed my first teacher, Professor W.E. Agar, who wrote a little known but important book, "A Contribution to the Theory of the Living Organism" (1943). I believe that all of them would have agreed with J.S. Haldane that personality is the great central fact of the universe. Life, as I have argued, can be understood at different levels, but the most elusive level is the phenomenon of mind and consciousness that we ourselves are aware of and which we assume is characteristic of at least some of our nonhuman colleagues. But it is developed in us in a paramount way. This is the most incredible aspect of the living organism, that it is a subject and not just an object; that is to say a being that experiences and has feelings. You could hardly call a human who was without any feelings at all alive in any real sense. To live is to be responsive in a feeling way. Now you may say give the brain physiologists time enough and they will come up with an answer. But, oddly enough very few of them are interested in the problem of mind and consciousness. There are exceptions,such as John Eccles and Roger Sperry, both of whom insist that consciousness is a reality and itself a causal agent. The search for light in this area is doomed as long as biologists suppose that classical physics can tell them what the real world is like and that life and consciousness are properties that emerge like secretions from bits and pieces that are completely without any elements of life or mind. That is to believe in miracles. That model falls apart especially now that physicists such as David Bohm claim that there are no fundamental particles. The image was all a huge mistake stemming from Democritus and thence from the interpretation of Newton in terms of a billiard ball universe.

Physics is moving onto the new frontier away from its old fundamental particles to a more unified theory that is much less mechanical. As one of the architects of the new physics David Bohm remarks, "the question of whether the basic laws of physics are in fact mechanical or not is of the utmost importance to biology .... it does seem odd therefore that just when physics is moving away from mechanism, biology and psychology are moving closer to it. If this trend continues, it may well be that scientists will be regarding living and intelligent beings as

mechanical, while they suppose that inanimate matter is too complex and subtle to fit into the limited categories of mechanism." (Bohm, 1969). The point is that the present categories of mechanism within which the biologist constructs models of life are too constraining. They will not enable us to move into the new frontier in the way in which physics is moving. This is not to say that mechanical models are invalid. On the contrary, they are basic to biology, but they have their limitations which we should now recognize instead of being blind to the constraints they impose on our thinking.

We say this is an age of science. This is a misleading half-truth. Ours is a transition period of an incomplete, unbalanced science lacking basic clarity because it has tended to ignore internal factors and causes, and has included only external causes or relations. We are fundamental ignoramuses. There is an enormous gap between what we experience and our understanding of that experience. Experience which involves internal relations cannot be understood in terms of a science that deals only with external relations. People are not just objects that are pushed around by external relations. We have internal relations that transform life. And why is this not true of other living organisms and for that matter of all entities.

I am arguing for a much more adventurous and exciting assault on life. We have become too restrictive. The brain functions as a sort of reducing valve that shuts out the universe so that the individual can do what is immediately in front of him. The million signals a second must be reduced to a few. But the creative intuition and imagination can be trained to remain open to the possible worlds yet to be discovered by a more holistic science. We have to lift our gaze from the immediate to the wider horizons. But that will demand a scientific revolution as large as that of the 16th century in which we see in T.S. Kuhn's terms a new paradigm or a new gestalt. To see a new gestalt is not to analyse things into pieces but to have a vision.

Scientific rationality has gained much for the world but it is also letting us down. In so far as it leads to a mechanistic model of life and the universe, it is contributing to the current world malaise of meaninglessness and despair. It is no mere coincidence that the search for meaning through way-out sects and fundamentalist religions is growing fastest in the new centres of technology such as silicon valley in California. The technological view of the world is life threatening. We need a life enhancing view of the world. It won't come from the simplistic and fundamentally false doctrines of the sects. It is emerging from a new awareness amongst some young people who have not turned their backs on science but who seek a transformation of science because of the depth of their human experience. This is happening simultaneously in a number of places like flowers in spring, beneath the ugly wreckage of a past civilization. I think in particular of a group of students in Amsterdam who provide a course which they call "The transformation of Science". In their discontent is an expression of a widespread determination to reconstruct a view of life and a way of living in the light of a rich experience and a rich conception of what it is to be human, In that great endeavour biology has a critical role to play.

REFERENCES

Agar, W.E., 1943. A CONTRIBUTION TO THE THEORY OF THE LIVING ORGANISM. Melb. Univ. Press.

Bohm, D., 1969. *In* TOWARDS A THEORETICAL BIOLOGY. 2. Sketches. An IUBS Symposium, pp. 29, 34. C.H. Waddington(Ed.) Chicago: Aldine Publishing Co.

Haldane, J.B.S., 1927. POSSIBLE WORLDS, AND OTHER ESSAYS. London: Chatto and Windus.

Hardy, A.C., 1965. THE LIVING STREAM: A restatement of evolution theory and its relation to the spirit of man. London: Collins.

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