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PRESIDENTIAL ADDRESS

THE WOES OF A BIOLOGIST

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A couple of years ago at a social gathering, I listened to a graduate student in organic chemistry bewailing his ignorance about his subject. He had studied organic chemistry for four years after graduating from college, and he was about to receive his Ph.D. in it, yet he complained that the amount of organic chemistry he knew was tiny compared with the vast amount he didn't know.

"But," he said, "I have a good working knowledge of biology."

Naturally, I was curious to know what constituted a good working knowledge of biology, so I asked him how many courses he had had. He told me: "A year in high school."

I said that his knowledge of biology wasn't any better than a person's knowledge of chemistry would have been if he had had only a year in high school, but I didn't convince him. "I keep up," he said. "I read the *Scientific American*." I told him that even this wasn't enough, but again, I doubt if I convinced him.

Now, this ignorance of biology on the part of a specialist in a sister science is bad enough, but what is really appalling is the fact that he didn't even recognize his ignorance.

And even more depressing is the fact that his opinion is quite typical of that of other chemists and physical scientists.

What is wrong? I have taken quite a few chemistry courses, and I read the *Scientific American*, too, but I don't consider myself an expert in chemistry. And biology is much more complex than chemistry. It contains too many apparently unrelated facts, too many details of too many different kinds, for one to be able to grasp them all. This is one reason for the fragmentation of biology into many disciplines—not merely zoology, botany, microbiology, entomology, physiology and the applied fields of agriculture, medicine and veterinary medicine, but protozoology (still too broad), plant ecology (still too broad), molecular biology, fruit fly genetics, insect toxicology, amphibian taxonomy, neurophysiology, bacteriophage virology, and DNAology.

Each of these fields, and many others, has its own scientific society, and it is no coincidence that biologists have no single unifying organization like the American Chemical Society. The American Institute

of Biological Sciences, which was formed only recently, attempts to fill this need, but it is still a union of autonomous fragments and it still has only 43 "adherent societies" out of the great welter of biological societies—note that I said *only* 43; the total must be in the hundreds.

It is no coincidence, either, that the age at which eminent biologists made the discoveries for which they became famous is much greater than that at which eminent physical scientists did so. The average age increases from mathematics to physics to chemistry to biology; and again, this reflects the complexity of the field.

I think that one reason for that young chemist's attitude is that biology is not such an alien subject that he realizes that he must approach it in total ignorance—from the outside—and learn it as something fresh and new and different. No. . . . He is already familiar with it. After all, man is a biological object, he lives and moves in a biological world, and we acquire quite a bit of information about ourselves and our biological environment simply by living and reacting.

This familiarity makes us feel that we are experts, but we really aren't. I am perfectly familiar with my TV set. I know the principles by which it operates, I know how broadcasts are transmitted and picked up, and I know what is happening to produce the picture on the tube. But my knowledge is really vague. I certainly couldn't qualify as a TV engineer or research worker or even as a repairman. I know this, and I wouldn't try, but my young chemist friend doesn't realize it

about himself and his knowledge of biology.

Well, that is one of the woes of biologists—we are misunderstood. But that certainly doesn't make us unique. . . . *We* are misunderstood, but so is everyone else.

Our woes are due to the results of this misunderstanding. Whatever field we work in, if we come up with ideas which contradict ancient and hallowed ones, we are liable to be attacked as corrupters of youth, enemies of religion, and monsters of iniquity.

The history of the theory of evolution is too familiar to need repeating. This theory is one of the foundation stones of modern biology, yet there are still people who consider it false and heretical, and there are still laws in this country which forbid its being taught.

Actually, there is one perfectly logical counter-explanation of the facts which are used to prove the theory of evolution. This explanation was advanced in the last century, and it has never been proven wrong. It is the view that all the fossils didn't get into the rocks where we now find them thru the processes of evolution, but that God put them there at the moment of creation—as a test of our faith. You can use the same argument to explain the processes of embryological development and the phylogenetic relations of existing organisms, too.

This argument may not be a satisfying one, but it is incontrovertible. As W. C. Dampier (1949) said in his *History of Science*, if I wished to contend that the universe and everything in it were created at 8 o'clock yesterday morning and that we were

all created at the same time with appropriate memories, no one could *prove* me wrong.

We ignore this sort of thing, for to accept it would mean the end of all science, but it's still a clever ploy.

Another area where we biologists get into trouble is in the field of population increase and birth control. The population crisis and its significance are well-known to all, but it is only recently that the topic has become fashionable—or even fit for polite drawing-room conversation.

Man's basic needs are the same as those of other animals—for food, for reproduction, for conditions which will enable him to survive as an individual and as a species. Many factors affect his achievement of these needs, but, stripped right down to their essentials, the most important and the most basic ones are just two: (1) population; and (2) food supply.

The population crisis is largely a result of advances in the health sciences, in the agricultural sciences, and in the other biological sciences—and it is these sciences which are going to have to cope with it, or at least provide the means for coping with it.

The world population is now about 3 billion, but it is increasing rapidly. I shall mention 3 divergent estimates. The most conservative is that of United Nations demographers; they estimated in 1960 that the world population will have reached 6,267 billion by the year 2000—that is, it will have more than doubled in the next 40 years (Deevey, 1960).

A more dramatic—if somewhat facetious—estimate is that of von Foerster, Mora and Amiot (1960).

They set Doomsday at Friday, 13 November, 2026 A.D. On this date, they said, the human population will approach infinity if it continues to grow at the same rate as it has in the last 200 years. Our great-great-grandchildren, they said, will not starve to death—they will be squeezed to death.

Philip M. Hauser of the University of Chicago was much more conservative. Essentially, he accepted the UN demographers' estimate, but he extrapolated from it that, at the present rate of growth, the human population in the year 6200 A.D. would "consist of a massive ball of flesh expanding on the surface at the speed of light." (M.R., 1963). . . . That isn't infinity, you see, and it also gives us 4000 years more than von Foerster.

It hasn't been too many years ago that people didn't worry about the population increase. They didn't understand that growth rates are inexorable, and they thought that agricultural progress would provide enough food for any foreseeable increase in population. I saw an article in *Science* only 7 or 8 years ago which preached this dogma, but I forgot to note down the reference, so I can't embarrass its author now.

Naturally, all the estimates of future population that I have given you are wrong, and no one knows it better than the estimators. These estimates are like the one that, if all the houseflies that had managed to survive the winter were able to reproduce at their normal rate, the earth would be covered by a layer of houseflies five feet—or is it five miles—thick by the end of the summer.

Thomas R. Malthus (1798) pointed out what was happening in his famous book, *An essay on the principle of population*, which was published in 1798 and revised in 1803. Malthus said that the population increases at a geometric rate while the food supply increases at an arithmetic rate and, as a consequence, poverty and distress are the unavoidable lot of mankind. In his first edition, he said that war, famine and disease are the only restraints on population growth; in his second edition, he added "moral restraint."

Looking at the situation today, I'd say that starvation will be the most important of these limiting factors. I don't think that we'll blow the whole species off the globe—or at least I hope not. And medicine is too efficient to let plagues get very far. So that leaves starvation.

Or does it? Malthus talked about "moral restraint" as a fourth factor, but no one who understands human nature takes it very seriously. Infanticide might be mentioned, too; certainly it was practiced in many places, including ancient Sparta.

Birth control—which is what Malthus was getting at by his "moral restraint"—is the only acceptable alternative. Biological research has given us the means of accomplishing it, and continuing biological research will make it easier, cheaper and more effective.

But society in general looks on biologists with deep suspicion and distaste because the solution which they have proposed—the solution that involves the least amount of human suffering—is contrary to the teachings of some religions and to the desire—widespread among hu-

man societies—to be fruitful and have many sons.

Biological warfare is extremely inefficient as a killer of mankind compared with atomic warfare; its efficiency in comparison with that of the hydrogen bomb is vanishingly small. In a modern society, where the whole population can be vaccinated, I'm not sure whether biological warfare would be more deadly than the bow and arrow.

But death is not the whole story, of course, and I'm not trying to defend biological warfare or any other type of warfare. The threat of biological warfare would cause considerable inconvenience and would require a certain expenditure of manpower and money to cope with it.

Why are people so terrified by the idea of biological warfare? Why do they look on scientists who are working on it with more revulsion than they do scientists who are working on nuclear warfare? Perhaps it's because they can conjure up a mental picture of themselves suffering from some nauseous fever—which must, of course, be worse than any they have ever had—whereas the idea of their being instantaneously converted into a ball of gas along with a few million other people has absolutely no meaning for them.

We are in the midst of a vigorous campaign against insecticides and other pesticides, and again the biologists who are developing them and who advocate their use are under attack. Automobile accidents kill about 40,000 people a year in this country and injure I don't know how many hundred thousand more; pesticides kill perhaps a couple of dozen, most of whom are engaged in their manu-

facture or commercial use.

There is a great outcry against the death of robins and of fish from accumulation of residual insecticides. But the introduction of the English sparrow and the starling eliminated more songbirds than insecticides ever will, and our rapidly expanding asphalt and concrete cities make life impossible for songbirds in places where they once flourished. And as for the fish, industrial pollution and sewage pouring into our streams have killed more fish and destroyed more aquatic wildlife than pesticides ever will.

Why, then, single out the biologists for attack? An important reason is, I think, that by blaming them we don't have to blame ourselves.

The automobile death problem can be solved easily enough in theory, but only at the expense of added personal inconvenience. All that we'd have to do would be to shift from private automobiles to public transportation. We'd have to set up a system of cheap, rapid, convenient public transportation — preferably electric—but this wouldn't be impossibly difficult. We'd have to restrict the manufacture of private automobiles, too, so that people would be forced to use public transportation.

Again, this wouldn't be impossible and it would bring with it many advantages. Our tremendous traffic snarls would be eliminated, and smog would no longer be a serious problem in cities like Los Angeles. We couldn't sprawl our houses out over the countryside, and cities would become more concentrated. This would release land for the added food production which we shall soon be needing. . . . Not that I expect

this to come about just yet—it will take another few generations, I suppose.

But the most virulent attack on biological science is that mounted by the antivivisectionists. These people are opposed to the use of animals in research or in teaching, regardless of the fact that they are needed to protect and improve the health and welfare of human beings. This is a crackpot attitude, of course, and a great many antivivisectionists are crackpots, but they have also drawn in some people with the most honorable of humane motives—plus a few who make a good living by working for them. Quite a few sweet old ladies have left quite a lot of money to antivivisectionist societies in their wills, and it's being used.

The activities of these people have forced many biological and medical scientists to take time from their work to defend themselves and to fight for the right to continue trying to help mankind. Francis B. Sumner (1945) of the Scripps Institution of Oceanography said in his autobiography, *The life history of an American naturalist*, "I think that it has been the despicable tactics of the antivivisectionists that have stirred me to action more than anything else. Their complacent ignorance of all the essential data of the case, their deliberate misrepresentation of facts and intentional garbling of quotations, and their persistent slandering of deservedly honored men of science do not predispose one to treat them as fair opponents."

Scientists are not sadists, but the antivivisectionists would want you to think that they are.

I could go on at great length about

the current epidemic of antivivisectionist activity. There are several bills now before Congress, ostensibly to provide for the humane treatment of animals used in experiment and research; most would seriously hamper research, and some are actually vicious, but the gory details would take another talk.

The humane treatment, care and welfare of laboratory animals are important matters. Improved facilities and more well-trained caretakers are badly needed, and no one knows this better than the scientists who use animals in their research. Unfortunately, many discussions of the subject are laden with emotion and irrationality, and the quarter-truths, distortions and slanted misstatements employed by antivivisectionists and their dupes serve only to confuse and misinform the public.

Why do some of these people—many of them sincere and honest—take this view? I believe that it is one more evidence for the validity of C. P. Snow's concept of the two cultures. These people are ignorant of science and basically hostile toward it. They have seized the slogan of humane treatment of laboratory animals as a means of belaboring science because they think—perhaps subconsciously—that it will be effective.

It will be. People who try to be completely factual and accurate and truthful are bewildered and quite helpless when they try to argue with people who twist the facts to make their point. Scientists don't know how to deal with antivivisectionists because they find it unworthy and impossible to meet them on their own slippery ground.

Enough of this. Are there any general features of this attitude toward biological science? There seem to be at least three. The first I have already mentioned: The superficial familiarity with the subject that gives people a false feeling of knowledge and competence.

The second I have hinted at: It is an example of the lay public's attitude toward science in general. The lay public knows that science is important, that science is the foundation stone and the building stone of modern civilization. Scientists are the priesthood of this new culture. Their esoteric knowledge and their special qualifications are required to make it function, so they have a special, elevated position in it. And, like the religious priesthoods of earlier days, scientists are viewed with a mixture of awe, fear and resentment. The basic antagonism between scientists and non-scientific scholars is expressed by C. P. Snow's concept of the two cultures, and the antagonism between the intellectual and the non-intellectual is similar.

The third feature, it seems to me, is the absence of the quantitative approach. Man likes his explanations simple: right and wrong, good and bad, black and white, plus and minus, all should stand out sharp and clear and separate. If research on animals causes some of them pain, then that research is wrong and should be stopped. If pesticides kill some song-birds and fish and a few men, and if over the years they might be accumulated in the body and cause some sort of obscure symptoms, then they shouldn't be used. If a large amount of fluoride can poison, then a small amount shouldn't be added to the

drinking water to prevent tooth decay. . . . If aspirin kills some children every year, then no one should use aspirin. If some people are alcoholics, then no one should be permitted to drink beer.

The last two conclusions are obviously ridiculous, but the first three are no less so. Biology is not simple; it is complex. Small amounts of substances don't have the same effect as large amounts. Many factors work together in many different ways to produce any one effect. And the same cause doesn't always have the same effect. Biologic phenomena are really statistical concepts. Basic to biology is the probability curve—the curve of random distribution.

Any one action produces a whole range of results, some desirable and some not. What we have to do is determine what these results are, find out which and how many have desirable or undesirable effects and to what degree, weigh the good effects against the bad, and then decide whether we should pay the price.

Do you want hundreds of millions of people to get malaria each year and millions to die of it, or do you want a few more fish in the rivers? Do you want your corn and cabbage and apples cheap and free of worms, or do you want more songbirds? Do you want your children to be vaccinated against polio at the cost of thousands of monkeys' lives, or do you want your children to take their chances on getting the disease? When you get pneumonia or enteritis or septicemia, do you want to take a drug and be cured—and take a chance on drug sensitization or side effects—or do you want to go back to the good old days when plague and

cholera and tuberculosis decimated the population and most people died before they were 35? Do you want to sneeze your head off during the ragweed season, or do you want to put up with a little sleepiness for a while? Do you want biologists to slow down their search for a cancer cure? Do you want the man who is going to operate on you to learn his surgery on a lot of dogs and a few people, or on a few dogs and a lot of people? This is the type of choice we face, not the simple one of the superficialists.

A couple of years ago in an editorial in the *Saturday Review*, Paul Woodring (1964) quoted a recent comment by the well-known humanist, Jacques Barzun, "The liberal arts tradition is dead or dying." Woodring agreed, and then went on to deplore the trend.

Woodring then defined the liberal arts tradition. It is "a vague one that has been corrupted as often by pedantic scholars as by those who prefer vocational training. But, in its best form, it stands for a kind of broad education that frees men of the limitations of ignorance, prejudice, and provincialism. Such education is needed now even more than in the past because the leadership of a complex society requires the ability to make value judgments based on a broad understanding of many fields of knowledge not closely related to vocational competence."

Who could disagree? We need more people with this broad type of education. But Woodring then went on to talk as tho a liberal education consisted of the humanities alone. If this were so, then the liberal arts tradition is decadent, and the sooner

we dispense with it, the better.

In the Middle Ages, a liberal education consisted of the trivium and the quadrivium. The trivium of grammar, logic and rhetoric led to the Bachelor of Arts degree, and the quadrivium of arithmetic, geometry, astronomy and music to the Master of Arts degree. We have a word that fits the idea that these subjects constitute a well-rounded education—trivial. This word is derived from the type of discussion that went on in cheap wine joints (which were usually located at the intersections of three roads—also trivia), but both derivations could be equally valid.

A liberal education nowadays must include not only the humanities but also the sciences. To quote Woodring again, "Such education is needed now even more than in the past because the leadership of a complex

society requires the ability to make value judgments based on a broad understanding of many fields of knowledge."

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