From this we can determine the relations between the variance of Z, X and Y. Then V(Z), the variance of the resulting Z about its mean, will be $\Sigma\ (\Delta Z)^2/N$. If we square both sides of equation (a) we get

$$\Delta Z^2 = \left(\frac{\partial Z}{\partial X}\right)^2 \Delta X^2 + \left(\frac{\partial Z}{\partial Y}\right)^2 \Delta Y^2 + 2\left(\frac{\partial Z}{\partial X}\right)\left(\frac{\partial Z}{\partial Y}\right)(\Delta X)\ (\Delta Y)$$

Now, $\Sigma\ (\Delta X)^2/N$ and $\Sigma\ (\Delta Y)^2/N$ are the variances of X and Y, respectively, *i.e.*, V(X) and V(Y), respectively. Then,

$$V(Z) = \left(\frac{\partial Z}{\partial X}\right)^2 \frac{\Sigma\ (\Delta X)^2}{N} + \left(\frac{\partial Z}{\partial Y}\right)^2 \frac{\Sigma (\Delta Y)^2}{N} + 2\left(\frac{\partial Z}{\partial X}\right)\left(\frac{\partial Z}{\partial Y}\right) \frac{\Sigma\ (\Delta X)\ (\Delta Y)}{N} \quad (b)$$

However, since X and Y are independent their covariance will equal zero, then

$\Sigma\ [(\Delta X)\ (\Delta Y)]\ /N$ will equal zero. Thus

$$2\left(\frac{\partial Z}{\partial X}\right)\left(\frac{\partial Z}{\partial Y}\right) \frac{\Sigma[(\Delta X)\ (\Delta Y)]}{N} \quad \text{will vanish}$$

and $V(Z) = \left(\frac{\partial Z}{\partial X}\right)^2 V(X) + \left(\frac{\partial Z}{\partial Y}\right)^2 V(Z)$

Now, if $Z = XY$, then $(\partial Z/\partial X) = Y$ and $(\partial Z/\partial Y) = X$ and

$$V(Z) = Y^2\ V(X) + X^2\ V(Y) \quad (c)$$

Now, if $Z = Y/X$, then $(\partial Z/\partial X) = -Y/X^2$

and $(\partial Z/\partial Y) = 1$ and

$$V(Z) = \frac{Y^2}{X^4} V(X) + \frac{1}{X^2} V(Y) \quad (d)$$

Formula (c) determines the variance of a product while formula (d) determines the variance of a quotient. These are large sample approximations.

THE OBLIGATIONS OF THE BIOLOGIST

HAROLD E. ALEXANDER
Arkansas Game and Fish Commission

In discussing this subject before this select group, it might be more appropriate to refer specifically to the wildlife biologist or resource manager, since most of us like to think of our job status in such terms. My reference to the larger designation, the biologist, is deliberate. Because, in this world of science and scientific marvels, which have vastly increased the scope and quality of our existence, and have, likewise, brought us to the edge of "Doomsday", there is no longer a point at which any segment of biology, or, for that matter, any aspect of science may be separated from any other science, or from the social or ethical codes or systems by which we live. Only a few years ago, the lives of people (and of biologists) were relatively insulated from what went on outside the immediate scope of their endeavor. Today, in this age of jetplanes, antibiotics, synthetics, high speed presses, pesticides, and the megaton bomb, nobody, and least of all the scientist who has been largely responsible for the creation of such a world, is any longer separated from what goes on outside the realm of his particular speciality. But as we acknowledge the mighty force of science, and take pride in the advances it has brought about in human welfare, we are, likewise, aware of the limitations of science. The physical scientist has made us particularly aware of this; for with the development of the atom bomb, he created a force which threatens man's extinction, and which does not acknowledge or enlarge on the limitations of his moral and ethical responsibility. Neither the biologist, or any other scientist, can longer

lead the "ivory tower" existence, with which they have been credited in the past, but must acknowledge their obligations not only to their professional codes, but also to their situations in the social and moral world of other men. They must assume a personal responsibility for the end results of what they do. They can no longer escape responsibility through the divisions of labor they have set aside for themselves.

We would note, too, that science, which is concerned with the discovery of truth, can be perverted. Its findings have often been exploited, not necessarily for the betterment of mankind, but for military, industrial and political purposes, and to exalt the prestige of nations (AAAS Comm. 1960). It has been used by promotors and charletans to attain their nefarious objectives. In view of this, the scientist cannot fail to be concerned about the uses to which his knowledge is put.

The scientist must be concerned with the "interaction of science and society" (Stewart, 1961). Even in the field of wildlife management we have maintained a separation between what was found out, and what was done. In the light of our experience, such a separation is no longer possible. The researcher has a moral obligation to promote the application of his knowledge to the best interest of society.

The biologist today is, I believe, in a unique position. Although we have been concerned primarily with technological advancements, we are discovering that technology is not enough. We are discovering that we, like other forms of life, have "biological" limitations; that we have environmental and esthetic needs which are necessary, to our physical and emotional welfare; and that ethical considerations, goodness and truth, and beauty, are essential to the fulfillment of our destiny and even to the survival of man. For the wildlife biologist I believe there is a particular place in the future of science and society, for by training he is concerned with the interrelationships of living things, and people are among those things.

The biologist, through his understanding of resource limitations, must be a conservationist. In the future he must be more and more concerned not only with resource management, but with what one writer has called "social conservation". Today, the subject of conservation is people (Romney, 1960).

In the future the biologist must be more than a technician. He must function as an educated man who is able to apply his special knowledge to the betterment of society and the advancement of welfare. As a bio-ecologist, whose business is the study of environment, he is well adapted to a role in the investigation and preservation of a balanced world in which men may live a satisfying beneficient life. In introducing the subject we have touched on the obligations of the biologist to his profession and to society. It shall be our purpose to elaborate further on these principles.

THE ETHIC

The biologist, first of all, is, as a member of the science profession, concerned with the discovery of truth. Further than that, he is obligated to the expression of the truth. He cannot, as a scientist or as a citizen, ignore that obligation. He must, also, be willing to assume risk to arrive at the truth. He must be willing to encounter adversity. He must acknowledge error, and be willing to accept criticism and ridicule. He must attempt to envision the end results of the application of his findings, be able to evaluate those results in terms of other scientific systems of analysis and other actions; and he must understand the social problems which stand as obstacles to the application of his knowledge to social betterment.

The scientist has been criticized by other men, and with reason. He has been accused of social neutrality, moral incompetence, and ridicule of areas of knowledge "not subject to precise measurement" (Quimby, 1954). Science has been feared because it represented change and "destructive force". He has been criticized for being "particularized", to the extent that his vision was myopic, and he could not see beyond the criteria which surrounded his specialty. He can no longer let specialization warp his vision. He must, in this time, become a socially integrated person concerned with the ramifications of his knowledge as it is related to other knowledge, and the end results of the application of all

knowledge. He is not only a scientist, he is a man with moral responsibilities.

In this complicated world the biologist must extend his knowledge to include the vast realms of scientific possibilities. He must recognize, too, that his specialty is only a segment of the whole. To quote Poincare, "We cannot understand an elephant by restricting ourselves to thin slices of him seen under a microscope."

Further, the biologist must understand that there are realms of knowledge to which the techniques of science cannot be applied. Somebody said "that you cannot extract the square root of a sonnet" (Dryden, 1954). In the application of our specialties to courses of action, we need to keep this concept in mind. In this connection, I believe the wildlife worker is prone to concern himself too much with numbers and bag limits. He needs to recognize that sport and recreation are primarily esthetic in nature. If this is not true, then all the efforts we give to perfecting fine tackle for fishing, skill in wing shooting, and our efforts to hunt in wilderness and seek out beauty in nature are wasted. We had best fish with seines and poisons, and kill our game by the most effective and lethal means. With this consideration in view, we need to give more attention to "quality" in sport as well as within other phases of our life.

I believe we have given too much precedence to what science can and has produced. Romney (1960) commented on "the dilemna of man enmeshed in the asphyxiating environment of his own creation (as presenting) the greatest challenge conservation has ever known. . ." As has been suggested, scientific findings and their results are only tools which may be used for human betterment or degradation. Their first use should be in the preservation of a wholesome environment for man. Someimes the preservation of such an environment is best accomplished not by altering things, but by leaving things as they are.

Possibilities of perverting the uses of science knowledge were thoroughly demonstrated by the Nazi ideology, which used anthropology to prove Arian superiority, biology to carry out ghastly experiments on suffering humanity, and scientific techniques to destroy millions of helpless people. Studies in biology have led not only to the control of disease, but also to the development of biological warfare. Reverence for technological achievement has a hollow sound, without the application of ethical and moral principles, to which the criteria of truth, goodness and beauty are basic. Of these, truth is fundamental to scientific endeavor. To quote (Piel,1954), "We can know with assurance only to the extent that we are informed on all the known alternative views." It is in the presentation of alternative views that the biologist must call upon another quality essential to his profession, and to his obligations. That quality is courage.

It has been said that a "serious man ought not to waste time stating a majority of opinion" (Weaver, 1961), which has already been stated many times over. The important thing is to examine the alternatives to established or proposed systems of action. In this connection, it can be observed that industry has used the benefits science has produced for profit, and this has been its main purpose. The military have used that knowledge to develop larger and better means for destruction, (and we acknowledge the necessities of the moment), and governments have used scientific developments for political purposes without concern for ethical motivations. Many times, as in the case of pesticides or atomic developments, the commercial interests or developers has insufficient knowledge of the effects of the use of these agents, or were unconcerned about such effects, subordinating them for profit motives. I believe both insufficient knowledge of their effects and indifference on the part of the producer and sellers have lead to a dangerous application of pesticide poisons to crop and forest lands.

Even though he will be criticized for retarding "progress", I believe it is the obligation of the biologist to evaluate the effects of these pesticides, of nuclear products on life and on social welfare.

We have other problems resulting from the "progress" of technology, such as pollution and water developments for limited purposes with unknown and often detrimental and long term results, which need careful study; and such studies are the business of the natural scientist (biologist). But those who dissent, who present a point of view at variance

with established or material objectives are sure to be criticized, ostracized or driven from their positions. Nevertheless, it is their moral obligation to state what they know, to present their findings so that we can know all the alternative views, and men can make intelligent choices from among the possibilities. The biologist has the obligation to give society the benefits of his position and that takes courage, without which the scientist is only a follower.

It has been observed that "conformity can be a cloak for the timid" (Weaver, 1961). The true scientist cannot retreat behind that "cloak of conformity". Courage is basic to the application of principle and to the very purpose of his existence. The only alternative is retreat from society and from his obligations.

PURPOSE AND KNOWLEDGE

The first criteria for judging the worth of any action is purpose. Science and culture cannot be separated. "Science is but one section of our culture." (AAAS Rept. 1957) Biologists and other scientists often seem to be more concerned with "method" and the "mechanizations of science" than with its relation to the cultural whole. The separation of knowledge and culture has been brought sharply to our attention through that development of the physical sciences, the atom bomb. Today the atomic scientist is fully aware that what he does cannot be separated from other affairs of men.

Thus, the philosophy and purposes of science have forced themselves on this group of scientists as a major consideration. But, the preoccupation with method and technique is still too apparent in the science journals. In seeking references for this paper, only three (3) references pertaining to the purposes and philosophy of science were reported in a major abstracting journal covering a three year period. In that same period, approximately 25 such references were listed in "Reader's Guide". These, almost invariably, were written by physicists concerned with the relation of nuclear research to human survival.

Although the primary effects of radiation are biological, the biologist is only just beginning to concern himself with the relation of the social and physical sciences to his field of endeavor. This lack of concern with social obligations is as apparent among wildlife biologists as among workers in other sicence fields. Preoccupation with techniques and methods of census, for example, is of little use to the wildlifer unless he can solve the social dilemna of the "buck law", and population counts of ducks or fish are unimportant unless the larger social factors, which result in vast drainage programs and in water pollution, can be solved. The problem of pesticide use and its effects on living things is unsolved, but it is a problem concerned with the application of biological data to social ethics. The fact that 6,000 commercial brands of pesticides are sold suggests that the commercial worth of these chemicals is the major consideration in their use. The primary purpose is profit; human welfare is considered secondarily.

The preoccupation with research for "practical" purposes is of concern to the scientist. It has been estimated that 10 billion dollars per year (Holton, 1960) are spent on research, of which only 7% is spent on basic research, defined as the "roots of the tree". Industry allocates large sums to practical research, only 3% of whch is spent on basic studies. For them, research must pay off in quick returns. In applied research, there is little consideration of the fact that all we know stands on a broad base of knowledge obtained through man's primary interest in the discovery of truth. Our knowledge of atoms or cells is basic to nuclear development and to advances in the science of medicine. Without these basic data, a progression to applied science is impossible. Of Federal appropriations, only 11% goes to biological and 2% to social studies. Yet the preservation of biological balances and social order are essential to preservation of those resources essential to men and to his survival.

Regardless of its necessity, it should be of concern to us that 84% of our research was motivated by military considerations in 1957 (AAAS Prelim. Rept., 1957). This, in part, accounts for our preoccupation with physical research, and neglect of biological and social studies. Such motivation warps the scope of our knowledge, and imposes restrictions

on our intellectual, social and personal freedom, which are fundamental to scientific achievement.

Of concern to many scientists and to us all is the problem of communications. For the scientists, there are 50,000 scientific and technical journals published annually. (Holton, 1960). They are poorly abstracted, and their results are available only to the select group interested in that phase of scientific subject matter reviewed. There is little or no effort to correlate the findings into any common fount of knowledge. It has been suggested that one of the great needs is a meeting of representatives of the various sciences to "bridge the barriers of specialization". Further hampering the dispensation of knowledge are restrictions on free communication, industrial, military; and due to the lack of any common "language" of communication, which can be understood by all scientists regardless of their specialty.

But of even greater concern is failure to communicate scientific information to the social groups which shape the uses to which knowledge is put. It has been pointed out that newspapers give only 5% of space to factual data, and T.V. programs allocate only 0.3% of their time to presenting scientific information (Holton, 1960). Scientists, themselves, fail to convert what they know into common knowledge, forgetting that men like Newton took pains to communicate their findings in popular form so that they became commonly understood. Since the scientist has a moral responsibility to other men, he must not forget that what is done with his knowledge is conditioned by political, economic considerations, and the character and motives of the users. He cannot escape responsibility for the application of his knowledge to purposes which may be good or evil.

In discussing this problem of communications, we finally get back to that basic ethical consideration, that the scientist is, first of all, a member of the human community, with moral and social and professional responsibilities, which are not divisible. As a solution to the problem of communications, several actions are suggested. These include the establishment and observance of a general code of ethics for all scientists, similar to the oath of Hippocrates, which provided standards and principles for the practice of medicine; the organization of general science societies which could integrate and relate the various fields of science to each other, and to the mental, spiritual, and physical needs of men; and more concern with the means and methods of communicating scientific knowledge so that all scientists and all men can profit from such knowledge. The world of science needs an active conscience that does not stand aloof from human needs, and self criticism to make that conscience an ethical force.

CONCLUSION

In summation I wish to observe that the biologist or other scientist can no longer separate his science or his purposes from those of other men. He must recognize that his knowledge presents only a partial view of life. He must know that the pursuit of truth is not enough, and that he is personally responsible, as are all men, for the application of knowledge to the ends as well as the means of life. He must recognize that his science in itself is amoral, and has no particular virtue; that without its application to the ethical concepts of goodness and beauty it may serve for either good or evil. The biologist must recognize that his concern with living things must encompass the understanding that the products of technology are not enough to satisfy all man's needs, and that appreciation of esthetic values and moral truths are essential to the perpetuation of the environment in which he must live. He must apply his knowledge of these complexities of environmental relationships to preservation of a world in which man can live out a wholesome and beneficient life.

He must recognize, finally, that he is not only a scientist but also a man with moral responsibilities. He must have the moral courage to say what he knows so that other man can profit from his special knowledge. He cannot hide behind that "cloak of conformity" which serves as a refuge for timid men ,and he can no longer stand aloof from the affairs of other men, but must come forth from the narrow niche of his specialties, and lead the way.

The white light of the hydrogen bomb which glows over the horizon and threatens men's very survival, has seared into our consciousness the awareness that material progress is not enough, and that the uses of science depend, finally, on the moral precepts which form the ethical codes, which govern the affairs of men.

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THE ELM SPANWORM—PAST, PRESENT, AND FUTURE

By R. J. KOWAL

Chief, Division of Forest Insect Research, Southeastern Forest Experiment Station Forest Service, U.S. Department of Agriculture

INTRODUCTION

Probably no forest insect in the Southeast has ever received so much publicity, aroused so much curiosity, and annoyed so many people as the now notorious elm spanworm which during the past five years has defoliated thousands of acres of hardwood forest in north Georgia and adjacent areas of North Carolina and Tennessee. In some 27 years of experience in forest entomology, 23 of them in the South, I have never known of a forest insect which received quite so much popular attention. There have been large-scale outbreaks of other leaf-eating insects before,