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Dr. Walter F. Bodmer of Stanford University gave a talk on "Training for Future Needs". His comments are as follows:

An important starting point for a discussion like this is the question what do we mean by Genetics? What is the content of Genetics and what is it likely to be in the future? Maybe, as Arno Motusky said, it is going to become so specialized that it will no longer be a single subject: there will be biochemists, neurologists, mathematicians, protein chemists, etc. I am sure, however, that we all agree that Genetics lies at the base of the whole of biology. It is necessarily a complex and diverse field in which you would expect this sort of diffusion. I do not believe, however, that the subject will become fragmented. I think that a geneticist is defined by his interests and that all geneticists are at least unified by their concern with genetic processes and their relevance to biological organization and functioning from the level of the DNA to that of the population and beyond, maybe into outer space. The result is, of course, a considerable diversity of activity among geneticists, which underlines the problem of deciding on the training needs not only for the future but for the present as well.

Bodmer

I would like to make two important preliminary points. The first is that there never can be a general answer to this question: you have to suit any selection of courses and programs to individual needs. There is much too much for a geneticist to know if you expect him to cover the complete field in depth. He could then study for the rest of his life and never do any research. I think the basic problem here is a very general one which has been touched upon earlier, namely the question of what to do with the "knowledge explosion". The training of a research worker has to bring him to the frontier of his field and at the same time provide a sufficiently broad base for likely future advances. At least part of the answer lies in the better coordination and cooperation between different specialists. Thus, in a medical school, there should be close ties between geneticists and M.D.'s. The second point I would like to make is that at present, as well as in the future, there is some sort of core of knowledge which a geneticist should have. I do not think anyone would agree as to exactly what that is except insofar as it expresses the common interests of the geneticists. Impossible as it may be to predict the future trends of Genetics, we have to advise students as to what they should do and maybe what we say to them now will itself have some effect in molding the future of our subject.

Any geneticist (in fact any scientist), should have a sound basis of mathematical knowledge. An important outcome of this should be the ability to think logically and to provide a rational analysis of scientific problems. Statistics, especially experimental design, are an integral part of this training. Though this is well accepted in agricultural schools and some medical schools, it is not so well accepted, for example, by biochemists, chemists or physicists, and I think this is very much to their detriment. There seems to be a feeling at the present time that mathematical biology will develop into a separate subject. I view this with some scepticism. Although it is extremely important for geneticists and biologists to have training in mathematics, I think they should end up by being primarily biologists and not mathematicians.

A natural corollary to a training in mathematics is the need to understand the use of computers. There has been some discussion earlier about language requirements. One of our requirements at Stanford is "Balgol", the local computer dialect. The use of computers, or at least the knowledge of how to use them, is going to become a more and more important part of the training of any scientist (and perhaps non-scientist), as automation catches up with us. Population genetics and the simulation of population genetic models were probably the first major applications of computers in genetics. Many more applications now exist and can be predicted. Genetic demography requires the analysis of data on a large scale, unmanageable without the use of computers. Simulation of other genetic situations such as the developmental process, will undoubtedly be important in the near future. Peptide and nucleotide sequence analysis, automatic counting of bacterial colonies on a large scale, and the analysis of the results of x-ray crystallography on large molecules represent a small proportion of the applications in molecular biology. In the near future the computer will play a very important part in the on-line control and analysis of our experiments much as it now does, on a larger scale, for the chemical engineer. This application of computers may well be one of the most revolutionary advances in scientific experimentation and research.

Some knowledge of physics, chemistry, physical chemistry, and biochemistry is essential for the understanding of molecular biology which is the study of biology at the molecular level. It is clear that there is going to be a large and important development in the understanding of the detailed functioning of biologically active macromolecules,which will require a very advanced knowledge of the physical and chemical sciences. The general emphasis I would make here is the importance of a good grounding now, and in the future, in these areas and the importance of trying to keep up with relevant advances in their understanding and technology. A very significant aspect of the development of genetics, and biology in general, is the advancing technology of the subject. This is really where we have to keep up with the people developing techniques in different fields and try to maintain close contact and association with them.

I have not so far discussed the need for a biological background, partly because this is a large section of most of the current training of geneticists and so needs no special emphasis, and also because I would include its most important aspects in the core of genetic knowledge. I certainly do not believe that the usual classical biological training with almost no emphasis on mathematics and the physical sciences is in any way adequate for the likely future needs of a geneticist. However, assimilation of a basic background in biology is, of course, essential since the primary objective of the geneticist must be to further understanding of biological processes at all levels.

The complement to the above discussion is to ask what are the likely future avenues of research in genetics. Any guess now is, of course, hazardous and likely to be proved incorrect. There are, however, two obvious and popular directions of research which certainly encompass a need for the type of training I have been discussing. The first of these is the understanding of the mechanisms of development and differentiation. The second is neurobiology, more especially an understanding of the chemistry of the mental processes. In the Genetics Department at Stanford, there is now a neurobiology section. It might be thought that this is somewhat far removed from the realms of a genetics department. However, these studies should ultimately result in an understanding of the genetics of mental ability, intellectual achievement and the basis for "normal" intellectual differences between people. The materials for such a study may well come from an investigation at the phenomenological level of the genetics of these variations aimed at establishing which people differ in a particular way.

There will always remain two problems common to all scientists now and in the future: (1) The problem of communication - of coming to grips with the vastly increasing amount of literature and knowledge that is continuously being poured out. It is important that there should be some support for teaching our students how to cope with this knowledge explósion. (2) The question of administration. How should we teach students to be prepared for the administrative problems they will have to face in the future. Perhaps one of the best ways to do this is to involve them in some administration at an earlier stage, for example, sending them to administrative meetings so they can find out for themselves how things do (or do not) get done.