INTERDISCIPLINARY ACTIVITY—ESSENCE OF MODERN RESEARCH

G. N. RAMACHANDRAN

Gita, 5, 10A Main Road, Malleswaram West, Bangalore 560055, India.

At the beginning of this century, the basic sciences had been broadly divided into four disciplines—namely Mathematics, Physics, Chemistry and Biology. The fields of activity obtained by the interaction between these fields were just emerging—such as Mathematical Physics, Physical Chemistry and Biochemistry. It is not necessary to emphasize the great strides that were made in these interdisciplinary subjects during the first fifty years of this century. Mathematical physics, or theoretical physics as it was more commonly called, was the spearhead of modern science. Quantum theory, relativity, and quantum mechanics, one by one, came into force and the experimental studies in physics and chemistry were vastly influenced by these; statistical mechanics had a large part to play in the study of chemical reactions and physical properties of materials; and chemical spectroscopy, in theory and practice, played a vital part in the development of chemical physics and molecular structural studies. Biochemical studies made it clear that the key to biological activity was chemical in nature.

We, in India, had somewhat accepted these newly emerging borderline subjects. In Departments of Physics, sections devoted to theoretical physics, and in Departments of Mathematics, sections devoted to applied mathematics, were established by many universities by the 1940s. So also, physical chemistry was well accepted as an important branch of chemistry; but chemical physics unfortunately did not get established as an emerging field of activity in physics departments, although spectroscopy was accepted. The physicists showed a certain reluctance to introducing chemistry into the physics curricula; and, at the time when this author was young and he was working on problems connected with molecular structure and properties of molecules, only a very few institutions were available in India, where chemical physics was accepted as a distinguished branch. Biochemistry, surprisingly, was established very quickly in our country; in fact one of the earliest Departments of Biochemistry in the whole of British Commonwealth was founded in Bangalore in the Indian Institute of Science in the 1910s and many biochemistry departments came into existence elsewhere quite early in the development of this subject.

Right at present, the cleavage between theoretical physics and experimental physics, between inorganic, organic, physical chemistry on one side, and biochemistry on the other, has got established in almost every department of physics or chemistry. However, in the fields devoted to the two extremes, namely mathematics and biology, our university departments did not show a tendency to acquire other borderline subjects to enrich themselves. Thus, many mathematics departments were reluctant to have applied mathematics in them, and applied mathematics was mainly found as a department by itself in the Engineering Colleges and Institutes of Technology. So also, biologists did not take to biochemistry and restricted themselves to biology as such, although its different branches like zoology, physiology, botany, microbiology etc were particularly emphasized in one laboratory or other.

Starting from the 1950s, many new fields have come into existence, and have become tremendously important. Without, in any way, trying to be exhaustive, we may list some of these, like computer science (by coalition of mathematics, physics and communication engineering), molecular biophysics (by the mixing of techniques of molecular physics into chemistry and biology), energy research (in which a very wide range of branches of science are involved), biopolymer science (by the mixture of physical and organic chemistry, combined with materials science), materials science itself (which requires a knowledge of theoretical physics, experimental physics, along with physical chemistry and chemical physics), and so on. Very recently these have been even further specialised, but at the same time made intensely active and useful, in fields such as biophysical chemistry, biotechnology, bioengineering, and so on. One does not know to which of these fields we will allot subjects such as drug research, genetics, ecology and so on.

It is not the purpose of the author to merely point out the existence of these intensely proliferating subjects. Rather, the idea is to emphasize that we, in India, should not be left behind in these modern developments of science, and we shall consider below some criteria and steps that are relevant for this to be achieved. (On purpose, the applied aspects of these subjects, such as space research, atomic energy, and so on, are not discussed, because they will properly come under the category of technology, rather than science, which is the main topic under discussion in this article.)

Firstly, training for interdisciplinary subjects must be made such that, while adequate knowledge and background of the constituent independent disciplines are given, the depth of each must not be made too large. Rather, it should be broad-based and a number of different subjects must be taught, belonging to different fields of science, but at the same time making them a coherent whole and keeping them deep enough for application to the particular interdisciplinary activity. As an illustration, we shall take the subject of molecular biophysics, with which the author is most familiar. Suggestions regarding the way in which this subject can be encouraged and developed have been given by a Committee headed by the author in the early 1970s to the University Grants Commission. However, even now, only a small number of laboratories in the country are well equiped both in men and materials to pursue research, or give training, in this subject quite satisfactorily. Briefly, this subject requires training in all the four branches of science, namely, mathematics, physics, chemistry and biology; but emphasis should be on physics (since physical techniques are the ones that are experimentally used) and chemistry (since molecular structure is the one that is employed for understanding the behaviour of biological materials). Going to the extreme left, enough mathematical knowledge should be available in order to work out the theoretical aspects, as in chemical physics and quantum chemistry, and enough knowledge of biology should be acquired, particularly in the field of biochemistry, in order to appreciate the nature and activity of the molecules that take part in biological systems. As a side dish, computer programing and usage must be taught, because most of the theoretical work is not done as a mathematical derivation, but rather as calculations giving specific information at the end—such as the energy of a molecular conformation, or the topological properties of a biopolymer chain.

Obviously, a laboratory catering to these needs cannot be located in a department purely devoted only to mathematics, physics, chemistry or biology. It should be fostered as an independent department, with skeleton staff which has highly specialised in this interdisciplinary field, but who would associate themselves with one or two experienced members of each of the four branches mentioned above, for collaborative teaching and research. This is one of the reasons why there has been a hesitation in starting the subject in most Universities. It has been our experience that persons, specially trained in this field by our laboratories, could not get a foothold in any of the departments of physics, chemistry or biology, because they were not specialised in any one of these as such. *Vice versa* in a few places, where molecular biophysics was taken as a special subject at the M.Sc level in Departments of Biology, the students were not given enough background on the mathematical aspects, so that they only had an extensive picture, but not deep intensive knowledge.

It may be wondered why there should be this difficulty, when a related subject like microbiology which also requires knowledge of chemistry, biochemistry, pharmacology and biology, could have risen and expanded in the country quite well, and contributed to the introduction of studies on DNA recombination in molecular biology. The reason is that microbiology is essentially an experimental subject and techniques can always be taught; but molecular biophysics is only partly experimental, while its essential basis is theoretical and mathematical, and it requires a sound background of molecular physics, which then is extended into chemistry and biology. Therefore, the author believes that this subject should be taught as a practically complete course in M.Sc, just like biochemistry is taught, and also that this should be developed first in a *department of physics or theoretical chemistry*, before making it an independent department. Chemical physics and molecular structure are the ones that are most important as a basis, and they can be taught in the physics (or chemistry) department itself, by persons who are specialised in spectroscopy and quantum mechanics. Only about 10 to 20 percent of the subject has to be taught by biochemists and in this the emphasis must be on facts related to molecular structures and the influence of the chemical nature and the shapes of molecules on their biological activity. Even for these, the *theory* is best appreciated and taught by chemical physicists, or physical chemists.

It is the author's belief that it was the attempt to incorporate biophysics, and more particularly molecular biophysics, in biology departments that has led to the relatively slow development of this subject in our country. In Europe and USA it is almost always found in departments of chemistry, or in a highly specialised laboratory in molecular biophysics by itself, forming part of biochemistry or biology. If, in India, we can make more physicists become interested in this subject, and get the activities of their department expanded in the direction towards biomolecular structure, then the subject of molecular biophysics will surely take firm roots. Just as a very special effort has been made to introduce biotechnology in many laboratories of biology and biochemistry, there is an urgent need to develop molecular biophysics in every department interested in subjects such as molecular structure and molecular spectroscopy, and their theoretical counterpart, quantum chemistry.

Whatever has been said about molecular biophysics is true also of the various other newly emerging interdisciplinary subjects and the need for their quick growth in our country. It may be mentioned that it is very necessary to provide opportunities for research in such fields *right at the time when the subject is emerging* in the advanced countries, if we are to keep in pace with the developments abroad. It was the good luck of the author and his collaborators that they entered the field in the late 50s and early 60s *when the fundamentals of the subject were being enunciated*, and therefore we in India were able to contribute something really useful to the subject. In fact, at the early stages of development of a new field, new ideas are more important than new techniques, or experimental facilities, and this makes it easy to work in competition with scientists in advanced countries. This should be borne in mind when young scientists attempt to establish new centres of research in interdisciplinary fields that have just come into being. Such activity can only take place in well established departments in one of the older fields and there should be sufficient flexibility for the funds to be quickly diverted from standard research into newer studies of a more provocative and speculative type. It is in evaluating the research projects of such a nature that a good amount of initiative is needed from the senior scientists for their moral support to the youngsters who take courage to enter such newer activities.

This does not mean that research in well established subjects which may be of importance should be put aside. Very often it is studies of a routine nature which lead to unexpected consequences, and which turn out to be crucial for the development of new ideas in well-known subjects. For example, the developments in nuclear physics during the last 20 years all came out of further extension of current technology and theoretical research going side by side, and right now the whole subject is in the melting pot and very fruitful consequences are expected to come out during the next five years.

However, this should not distract our aim to restrict ourselves to supporting and encouraging researches in new interdisciplinary fields, even to the extent of excluding too much of support for studies in well-established fields, for it is only when new approaches are made that new and original consequences come out. Very often, such new proposals may look strange and unrealistic at the beginning. There should be enough attention devoted by senior scientists to seeing through the possibilities and consequences of such fresh proposals, and encouraging them, even though they may not bear fruit in the beginning. There is a large responsibility put on the senior scientific community in the country in fostering the direction of research activities in the proper way, so that, even with the restricted facilities and opportunities that are available in the country, the bright young men who are available in the country can contribute substantially to the development of world science in the advancing fronts of knowledge.

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TINPLATE AND THE ENVIRONMENT

The impact of various types of packaging on the environment is of great concern these days, and a major packaging material such as tinplate must satisfy both consumers and legislators in avoiding excessive waste. This article in 'Tin and its Uses' No. 138 describes the progress made in recycling the used tinplate containers from domestic wastes, and schemes to recycle scrap tinplate directly back into the iron or steel making process. The trend to thinner tin coatings on the steel makes this type of process increasingly attractive. (International Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex, UB6 7AQ, England).