TRENDS IN BOTANICAL THOUGHT AND RESEARCH: IN RETROSPECT AND IN PROSPECT

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THE pursuit of knowledge through science, as indeed other human activities, has its moods and its fashions, its high periods and its depressions. Plant science also has been shaped by a series of such trends and it is a useful exercise to see them in retrospect and anticipate them in prospect. An excuse for the writer to do so is the fast approaching 50th Anniversary of his own entry, after graduation in chemistry, into botanical research. This exercise is also prompted by the recurrent question, repeatedly posed during a brief sojourn in India, how that so diverse country with its ancient traditions and great problems should adapt its scientific efforts (particularly in biology and botany) to the current scene.

The origins of botany and plant physiology are as ancient as the arts of agriculture and the use of plants in primitive medicine. One may, no doubt, still search for the origins of this, or that, botanical thought or principle in the ancient history and writings of India as in the culture of any other great centre of human development. Because the most modern developments of science have been so identified with the West, where the dramatic events of the XIXth century, with its wars and industrial revolution, paved the way for the accelerated scientific pace of the XXth century, most students have seen the history of botanical science in western terms. Following the histories of Sachs (1875) and of Reynolds Green (1909), the time course has been traced from Aristotle and Theophrastus to arrive, tortuously, *via* Van Helmont, John Woodward, Malpighi, Stephen Hales, Joseph Priestley, de Saussure at the turn of the XIXth century. Thereafter, the great procession of the XIXth century includes such names as Robert Brown, Nageli, Mendel, Pasteur, Hofmeister, De Bary, Sachs, Strasburger, Pfeffer, De Vries, Haberlandt. But in any search for ultimate origins, problems still arise. The oft-quoted first plant physiological experiment of Van Helmont (1577–1644), even the first recorded experiment in nutrition and natural science, tested an idea that was in conflict with Aristotelian doctrine but was as clearly expressed 150 years before Van Helmont by Nicholas of Cusa (1401–1464) though it was not attributed to him by Van Helmont. It is an interesting question whether ancient Sanskrit manuscripts contain similar, or even earlier, references to such basic nutritional concepts.

But the XIXth century saw the dichotomous development of the interpretation of plants based on descriptive observations of their characteristics (through taxonomy, morphology, histology and cytology) and analytical interpretations of their functions (through physiology and biochemistry) based on a rational system of chemistry. It is a strange paradox that the monumental works of the XIXth century morphologists, that laid the foundations of botanical science, are now so often ignored, or even disparaged, in the search for causation in purely physical and chemical terms. It is a paradox because the physiological functions about which so much seems to be known in terms of the chemical steps by which they occur (*e.g.*, protein metabolism and synthesis; carbohydrate metabolism, respiration and photosynthesis; the uptake and accumulation of ions from dilute solution) still require that essential setting in the cell systems in which they occur in order that they may proceed at the pace, or with the efficiency, and under the requisite degree of control that the conditions *in vivo* demand. On the current scene no plant physiologist or biochemist can really afford to ignore structure and organization; he must in short be concerned with morphology.

The first hope and lesson is that students in India should still be taught the importance of perceptive visual and descriptive observations and that great insights may often flow from simple experiments. Those who, too soon, become the slave of their purchased equipment, or who regard its lack as a total barrier to all progress, may well miss the challenge that has set so many in the past on an original voyage of discovery. Pioneers like Stephen Hales, Priestley, Mendel, Darwin and others improvised and relied upon their powers of observation and interpretation—they were not fettered by slavish adherence to any currently acceptable school of thought or the acceptable kind of experimental approach.

But no current 'fashion' should be allowed to become arrogant and overbearing—to claim to be recognised as the sole respectable avenue to truth and understanding. So many fashions or fads of the past have flourished in their day until their limitations became apparent. The rise of cell physiology and the early thoughts that a knowledge of the composition and chemical substances of cells

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implied that this would lead to understanding, illustrates this point. In the 1920's people still wrote and thought about protoplasm as a material substance (not as an organisation), about its physical and chemical properties. But an early faith in the chemistry and chemical composition of cells *per se*, and in the application of the physics and chemistry of the day, which necessarily related to equilibria, soon gave way to the doctrines of General Physiology and the then 'new' thoughts that the meaning of life would emerge through knowledge of those properties that cells and their protoplasms had in common. General Physiology soon merged into General Cytology with its attention to membranes and cellular inclusions and later to the staining properties of self-reproducing organelles. Meanwhile, the advancing knowledge from protoplasm as the 'physical basis of life' to the nucleus and the chromosomes as 'the physical basis of heredity' laid the foundations for those borderline developments between cytogenetics and biochemistry that have later proliferated under the label of 'molecular biology'. But the doctrines of Comparative Biochemistry and of Biochemical Cytology each represented sequential 'fashions' along the way. And though the term 'Molecular Biology' really dates back to Astbury in the early 1930's, for whom it was really the molecular configuration (*i.e.*, architecture) of biologically important large molecules, it has come to mean the working out of the importance and role of the nucleic acids in the transfer and maintenance of genetic information and the means by which that information is translated into action through its ability to regulate biosynthesis and metabolism. There are even those today who go so far as to believe that no modern study can be worthwhile unless it has its component of 'molecular biology'.

But dramatic as the so-called Molecular Biology developments have been and even as the Nobel awards have proliferated, one can see clearly the limitations even of this latest, and most dramatic 'fashion'. Although widely hailed as the 'new biology', that is credited with being the wave of the future in the XXIst century, it is still very far from being a substitute for the 'old biology'.

Although molecular biology tells us much about how genetic information is uniquely established in the zygote of a sexually reproduced organism and how it is retained through successive equational divisions throughout development, it has yet to reveal the secrets of development, *i.e.*, how the persistent information in the DNA of the nuclei is so controlled and programmed that it 'tells' the cells what to do when and where they should. And this is so despite the elaborate, largely semantic, exercises by which we are told that this occurs.

In other words, morphology and embryology and anatomy (pursued experimentally with the modern tools of phase and electron microscopy into the fine structure of cells) are not, though essentially descriptive, outmoded; they are, in fact, as essential as ever if the 'new' or 'molecular biology' is ever to yield up the answers to the problems of development. But these problems of development and morphogenesis cannot be studied only on the simplest systems—one can hardly understand an oak tree or a palm with their organised growing regions and their elaborate morphogenetic responses, by work done only on *Escherichia coli* or bacteriophage. Therefore, one hopes that the Universities and especially the new centres of India will not put the bulk of their resources into slavish imitations of what has been done in the West since the end of World War II. Like so many earlier trends and doctrines that of 'molecular biology' may already have yielded its major returns.

This then is a plea for the maintained excellence of morphology, embryology and the study of morphogenesis—areas which in the past have both well developed in India. With a rich flora upon which to draw, containing many economically important plants about the growth and development of which so little is known, Indian scientists can describe the setting in which the principles of molecular biology can be intelligibly applied. But they may also show—unwelcome as this thought may be to some—that the morphological setting, through 'messages' yet to be deciphered may well control how the genetically prescribed biochemistry shall work. It may be currently fashionable to assume that cells must at all times 'ask their nuclei,' for permission to carry out this or that event. But surely the visible evidence of morphogenesis suggests that once the unique genetic information is conferred and is conveyed by successive equational divisions that cells, especially the 'totipotent' cells of higher plants, already 'know' how to do everything that is required of them. In fact, it is their morphological setting, which mysteriously 'tells' them how to use their innate information; not it seems gene by gene, activating or deactivating them, but bringing in *en bloc* large combinations of characteristics which link form and biosynthesis and metabolism. We seem neither to know how these comprehensive signals are given or how they are collectively perceived and rendered operative. In this sense, therefore, morphology and the environment or milieu of cells, as in the organised growing points of higher plants, 'calls the shots' and the biochemistry duly responds.

Thus, it is regrettable how over-anxious some young scientists, in India or elsewhere, seem to be to imitate the latest molecular biology tricks they have seen or heard about, often when abroad, and how they crave the latest in equipment by which to follow these latest fashions. Too often the current trend seems to be that we already 'know the rules' and nature is, as it were, being coerced to obey them. How much more rewarding it may be to recognise that even the new biology, conceived in molecular terms and in the language of the nucleic acids, may not yet have all the answers to the great problems of development, differentiation and morphogenesis? Here surely the role of investigators should be reversed. Instead of, as it were, prematurely dictating to nature in molecular terms, they should be listening in; 'tuning-in' by observation on those continuing 'dialogues' between nucleus and cytoplasm, between adjacent cells in their immediate milieu, between tissues and organs of the plant body as they determine and regulate 'divisions of labour', and between the organized growing regions of plants as they respond to environmentally induced messages, however they are perceived and transmitted into effect. So much that is to be done to sketch in this rich background of form and function, of stimulus and response, of environmental controls of metabolism, nutrition and morphogenesis threatens to succumb to the mistaken search for proofs of preconceived simplistic unitary explanations for the responses of essentially complex and non-equilibrium systems which are affected by so many variables and their multiple interactions. In fact, experimental plant physiology now needs those who are willing to work out devices for studying the interactions of so many simultaneously operating variables rather than attempting to study them singly in isolation.

One therefore hopes for a resurgence, in modern terms, of the older disciplines of morphology and anatomy with the use of all the tools (from hand lens to electron microscope) to render visible the events along the way from zygote to organism. One looks also for a resurgence of interest in the behaviour of plant growing points as they respond morphogenetically to the varied causal factors that control development. And the study of metabolism and biosynthesis, aided by the technical advances of all forms of chromatography and radioautography should not merely be thought of as an appendage to the role of genes in action, or seen in the image of a depressing static metabolic chart on a laboratory wall, but as one of the ways in which one can see the multiple interactions at work between environments and nutrients and organized cells and growing regions during development.

However, the pursuit of these problems, using many plants (some economically important which have not yet become stereotyped as laboratory objects) can be and should be adapted to the scale of resources available and to the level of investigation needed at the outset.

Would Darwin's Power of Movement in Plants or his Insectivorous Plants or Pollination in Orchids, or Mendel's work on peas, ever have emerged to change the trend of thought of the times unless the enquiring mind of a keen observer had addressed itself to the evident problem at hand? Of course, the time comes when, to pursue the analogy, the studies of Darwin on coleoptiles need the sophisticated studies of the biochemistry of growth factors and of their modes of action and the work of Mendel on peas, proliferating through that of others on *Drosophila* and *Zea mays*, etc., leads to and requires the sophisticated studies of nucleic acid structure and protein biosynthesis. But the point is that in each period and in each age there must be those who are not merely content to "follow the fashion" but who have the initiative and insight and curiosity to open up new areas as they seek, often by simple means, new light on how nature works.

Therefore, in the last third of the XXth century, building upon the great advances in cell physiology, biochemistry and genetics, there is both a great opportunity and a great challenge to determine how development works; in effect to know how nature, having elaborated rigorous mechanisms to preserve genetic identity, produces within this system such great diversity during development. In meeting this challenge botanists everywhere, and specifically in India, have a great and thrilling opportunity if they will adapt their enquiries to their resources, their experimental approaches to their problems rather than searching for problems that fit well-stocked laboratory or its pre-purchased sophisticated equipment.

In my humble experience the best ideas which have turned the course of events emerged often from experiments done simply—however sophisticated the later means to pursue them to finality became. This personal message to botanists and biologists in India is but a poor return for the stimulating experience of being Sir C. V. Raman Visiting Professor in the University of Madras but, having re-read the account of Raman's life and work, I would like to think that, in some respects, he might have approved.