night? What can contain greater excitement than finding out how a bat living in the deepest pockets of a labyrinthine cave knows time of sunset? There is a lot of biological and behavioural drama in the recognition by a bat mother of her own offspring, in the act of a bat relocating his 'personal space' ± 1 mm in the irregular geometry of a cave bathed in darkness, in unravelling how a mother field mouse by absence and presence gives her new-born pups information of day and night.

In this article I have been brazenly lobbying for more work in my areas of expertise and research interests. As the German proverb goes, 'the farmer does not eat anything that he does not know'. I leave it to other colleagues to hawk and commend to the reader their specializations in classical biology.

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Biotechnology, the tip of the iceberg

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Good traditional-biology research underpins biology's latest success.

I consider it a privilege to be invited to contribute an 'Opinion' article on the 'need of classical biology'. I have chosen to discuss the subject in relation to microbiology and applied botany. Biology is a vast discipline and the complexity of life processes makes it multidisciplinary and necessitates expert inputs also from physical and chemical sciences for understanding the component events of bioprocesses. Biotechnology aims at harnessing this knowledge for the benefit of mankind through manufacture of useful bioactive metabolites and production of plants and animals with better qualities.

In recent years scientific advances have pushed the frontiers of biological sciences at a rapid pace, and often 'modern' developments have been quickly relegated to the 'classical' within the span of just a few years. Yet, if one looks at the advances made in biology in perspective, it is possible to identify contributions of great significance in classical biology that have laid the foundations of several modern developments. For example, Mendelian laws of inheritance established in plants proved universal and led to the interpretation of genetics and heredity in molecular terms. The Nobel prize-winning work of Beadle and Tatum on *Neurospora* genetics was a significant milestone in this progress. Likewise, elucidation of the structure of DNA followed the classical work of Avery on biological variation in capsular pneumococci which led to the prediction that DNA was the molecule responsible for transmission of hereditary characters. The dawn of the molecular-biology era and the fruitful developments in biotechnology and recombinant-DNA technology, which have led to the successful cloning and expression of even mammalian genes in microbial systems, are outstanding offshoots of these classical findings.

The questions that present-day biologists and biotechnologists should address are: (i) What role does classical biology have to play in sustaining the progress in modern biotechnology? (ii) What is the type of infrastructure that must be built up and reinforced in classical biology to ensure sustained and fruitful advances in biotechnology? I shall attempt to find answers to both these vital questions from my individual perception as a biologist involved in using knowledge in classical microbiology and botany for developing useful bioactive metabolites.

Classical microbiological studies laid emphasis on ecology, distribution, taxonomy, and physiology of growth and reproduction of diverse forms of microbes collected and investigated by specialists in each of these major areas of microbiology. Such studies have laid the foundations for appreciating the extent of biodiversity in natural populations of bacteria, actinomycetes and fungi, besides other forms of microscopic life. We have considerable insight into the distribution of microbial populations, their correct identification, and their cultivation in the laboratory environment in pure cultures for exploring their biosynthetic activities as well as biotechnology potential. Although our knowledge of several groups of microorganisms is far from complete, the studies over the years have laid strong foundations for further advances in these 'classical' areas, provided such studies are pursued with vigour in future.

Biodiversity is now recognized worldwide as a major factor in identification of novel gene pools. While only about 1.5 million species have been described by biosystematists so far, experts have calculated that we may find that 70–80 million species exist if we study invertebrates and microorganisms more exhaustively[1]. Many of these natural populations are either endangered or becoming extinct owing to natural and man-made environmental changes. Conservation of the microbial heritage in well-established germplasm banks is vital to future development in microbiology and biotechnology[2]. An appreciation of microbial biodiversity necessitates generation of interest and adequate expertise in identifying the less-common genera and species from natural sources through enrichment and/or selective culture techniques. Since microbes coexist, colonize natural substrates, and are not distributed in uniform numbers, the rarer and slower-growing species can only be encountered through innovative approaches. Devising screens for such selections involves commitment to classical biology and high-level expertise in the taxonomy of selected groups and their physiology of *in vitro* behaviour to ensure long-term maintenance in pure cultures. Unfortunately, in recent years, focus on this vital aspect has been either very low or even absent, and, unless effective corrective measures are taken, future programmes in applied microbiology and biotechnology may be affected to a considerable extent. Adequately trained and skilled manpower as well as infrastructural facilities for ensuring *in vitro* conservation of microbes in accordance with established international standards are basic necessities for all countries if biotechnology programmes of the future have to be firmly established and flourish. Our own limited efforts at the National Chemical Laboratory have been very positive in that, by undertaking to screen for unusual microbial species with potential for development of novel industrially useful enzymes, we have discovered commercially promising strains of actinomycetes like *Chainia* and alkalophilic *Bacillus* species for cellulase-free xylanase production and *Conidiobolus* species yielding trypsin-like alkaline protease in submerged culture[3-5].

Considerable attention has been given in plant biotechnology to evolving improved varieties and cultivars for enhanced yields of food crops as well as crops with better nutritional value, such as better composition of seed storage proteins. Plant cell culture today has emerged as an area of great practical importance. Fundamental contributions made over the years by botanists, embryologists and morphologists to cell biology and studies of *in vitro* differentiation have been a major sustaining force behind all recent developments, including protoplast isolation, plant regeneration and differentiation, and somaclonal-variant selection. The use of the *Agrobacterium tumefaciens* plasmid is a major breakthrough in effecting transfer of desirable foreign genes into plants and 'synthesizing' desirable variants. There is, however, considerable need to strengthen our basic knowledge of plants, and continued efforts in aspects related to taxonomy, ecology, physiology, genetics and traditional plant breeding are most essential. Identification of wild relatives of crop plants that harbour genes for pest and pathogen resistance as well as stress tolerance would involve high-level expertise in such areas of 'traditional' botany as systematics and plant ecology. Even at the more fundamental and sophisticated level of plant gene manipulation, while considerable progress has been made in gene transfer, cloning and expression of desired traits, the success has been sporadic and rather inconsistent. The only way to overcome these bottlenecks is to get better knowledge of plant biology through intensive studies on the classical aspects viewed in the light of our modern knowledge. For example, at a recent symposium in Japan, Takeshi Otani of Kirin Brewery reported the successful creation of multiple lysine and tryptophan codons by site-directed mutagenesis in the gene for α-zein, the most abundant storage protein of maize. Although the engineered α-zein remedied the deficiency in the essential amino acids, the new protein was not incorporated stably into its normal location in the endosperm of maize.* Otani has suggested that further experiments using tobacco, which does not contain any zeins but where differentiation into whole plants from cell cultures is well standardized, are required for studies of the mechanisms of stable expression and accumulation. Another area of importance and concern to modern plant biotechnology is the inability of *Agrobacterium* to effect gene transfer into cereals, where such an effort would be most fruitful as well as essential. In a thought-provoking article Potrykus[6] concluded that failure to show proof of the recovery of transgenic plants among cereals despite careful and large-scale experiments using diverse established methods may 'point to a biological problem that has not been considered in previous experiments and which may also be the cause for the failure of *Agrobacterium*-mediated transformation'.

It is obvious that, whether it is with microbial systems or plants, considerable traditional or classical biological work must be done to supplement/complement the advances being made in modern biology. To establish sustainable biotechnology programmes, we must establish schools of excellence where persons skilled in the traditional and classical aspects of biology can be trained in the same manner in which we encourage research and development in the modern aspects of molecular biology and protein engineering. Under the impact of the molecular-biology 'wave' traditional biology has beaten a retreat, and several areas, like taxonomy, have become least-favoured areas for specialization among the upcoming generation of graduate and research students. Efforts to kindle interest in these neglected areas may have to be intensified without further delay if classical biology has to retain its rightful place in the future developments in biotechnology. A perspective view of the biological sciences must be emphasized by educational policy makers as well as funding agencies. The fact that classical biology is still the bedrock from which modern developments can spring must be firmly established at the earliest opportunity.

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