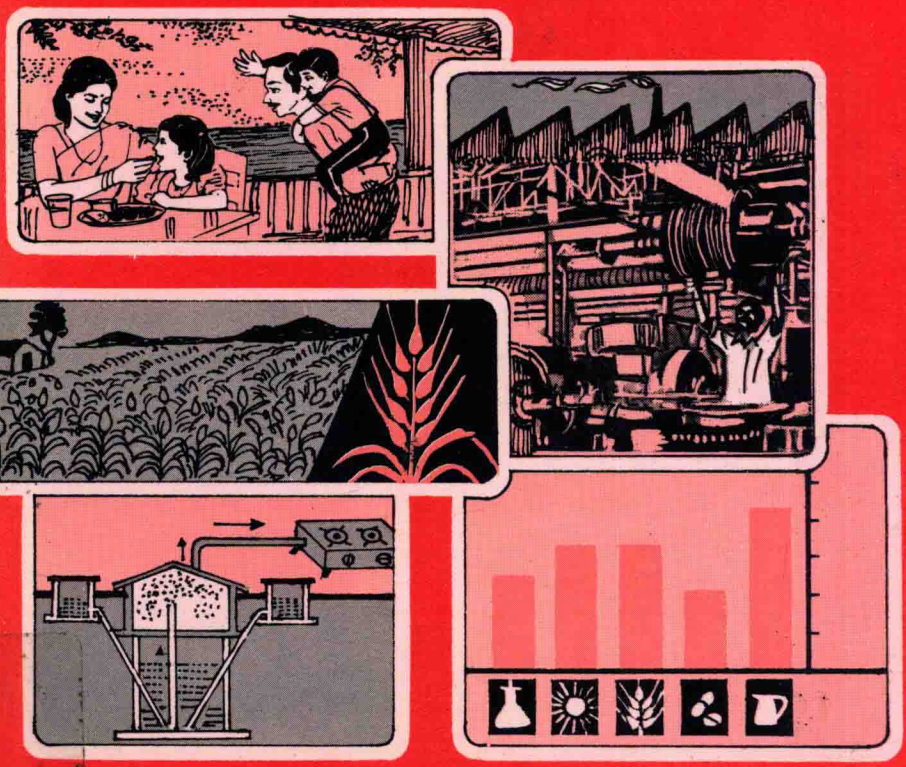
ADVANCES IN BIOTECHNOLOGY

S.N. JOGDAND



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Prof. S. N. JOGDAND

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ADVANCES IN
BIOTECHNOLOGY

DEDICATED
TO
MY FATHER

PREFACE

Though teaching, research and applications in the field of microbiology and fermentation technology have existed in our country for the last few decades, systematic efforts in the subject of Biotechnology started only in 1986 with the formation of the government-run Department of Biotechnology.

Many a times, students, researchers in allied fields, technical people in private and public sector organisations are not familiar enough with biotechnology. The volume of literature easily available is also relatively less. Moreover, many a times, books concentrate more on theory and principles. Hence, if biotechnology, its potential uses, its expanding market and impact on economic development is to be understood and highlighted, it will be worth while putting before the reader: Who is working on biotechnology? What are the current commercial activities in biotechnology? What are the future prospects of biotechnology?

So this book has been designed to put before the reader numerous examples of applications of biotechnology and its underlying principles. The text should be useful to undergraduate students of microbiology and other allied subjects as well as to all those technical and non-technical enthusiastic people who would like to get acquainted with biotechnology.

I express my sincere gratitude to Mr. D. P. Pandey and Mr. K. N. Pandey of Himalaya Publishing House, who realised the need of such book and encouraged me to write the same.

I am also grateful to Prof. H. V. Jadhav, Head, Chemistry Department, Modern College, Vashi, who wholeheartedly supported and boosted my desire to complete this interesting task. I am also thankful to Principal Dr. V. D. Patil, Modern College, Vashi and Prof. D. P. More who have encouraged me throughout this work by taking keen interest in its progress.

Nothing could have been possible without the availability of reference literature. I am really indebted to my friends, Prof. V. S. Pingle, Head, Microbiology Department, Birla College, Kalyan, Prof. (Mrs.) Jayashree Phadnis, Vivekanand College, Chembur, Prof. (Mrs.) Paramjeet Anthappan, Bhavan's College, Andheri, Prof. Dr. Vinay B. Rale, Head of Microbiology, Poona University, Prof. Ravi Phadke, Head of Microbiology Department, Ruia College, Bombay, Miss Kumud Goyal, UDCT, Bombay, for helping me to collect the necessary literature.

Lastly, my thanks are also due to my family members who let me work undisturbed and encouraged me throughout the write-up.

I wish I could impart the little that I have understood to the many who need it, to the many who can make use of it.

Vashi, New Bombay
1st January,1993

S. N. JOGDAND

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FEATURES OF BIOTECHNOLOGY

One of the most recently-quoted definitions of 'Biotechnology' is: "The applications of scientific and engineering principles to the processing of material by biological agents to provide goods and services."

The Spinks Report (1980) defined 'Biotechnology' as the application of biological organisms, systems or processes to the manufacturing and service industries.

Both these definitions are vague on the aspect of nature of organism or agents involved and, therefore, may raise a question as to: "Is agriculture itself a biotechnology?" But it is not so and most of the other definitions used employ this term only for the use of microorganisms and cultured cells.

The whole world today is so much shaken up with the word 'Biotechnology' that it has become a strong belief that this is 'the field' which will give solution to our 'any' problem. Biotechnology, no surprise, is then variously described as "the last revolution of the current century", "the third wave in the evolution of human ambitions," etc.

Biotechnology has the technical breadth and depth to change the industrial community of the 21st century because of its potentials —

(*i*) to give products which were never available before;

(*ii*) to give products that are currently in short supply;

(*iii*) to give new methods which will reduce costs substantially;

(*iv*) to give safer, better quality products; and

(*v*) to give products which will use cheap raw materials which are plentily available but not used.

Today, the world is facing four major problems — malnutrition, diseases, energy scarcity and its high cost and environmental pollution. To overcome these problems has become the objective of biotechnology development.

Biotechnology is applied today most vigorously in four major fields:

(*a*) Medicine and pharmaceuticals.

(*b*) Animal health, food industry.

(*c*) Plant agriculture.

(*d*) Chemical manufacturing.

Considerable work and applications of biotechnology are also seen in the field of environmental protection, pollution control, energy production at less cost, etc.

Recombinant DNA technology and genetic engineering have contributed a great deal to the development of biotechnology. However, biotechnology in its true sense is a multidisciplinary applied science, with its constituent areas — microbiology, chemical engineering, chemistry, biochemistry, genetics and immunology. Technological innovations are the result of convergence of several independent paths. The success of biotechnology still depends on the impact of modern biology on chemical engineers. Chemical engineers will have to become familiar with the language of biological scientists. Using rigorously-controlled conditions, high-purity chemicals, moderate temperatures, recovery of small amounts of products from dilute fermented liquors, suppressing unwanted metabolic pathways, keeping genetically-engineered cells viable and working over a long period are some of the new tasks for the chemical engineer to handle in the biological processes.

Success in biotechnology means economic success as well as scientific success. It is essential that process engineers are involved at an early stage in the planning of a venture in biotechnology. Biological, biochemical and chemical understanding of a particular systems may perhaps lead to a scientific success but a critical appraisal of the intended application on a large scale with considerations to man, material and money to be invested will give the judgement on economic success.

And still it is true that development in biotechnology has spelt so much success that it has left no area of human activity untouched and has been in a stage to revolutionise human life styles. Progress in biotechnology has been so breathtaking that what chemical technology has taken four centuries to achieve, biotechnology has achieved it in just four decades.

Teaching and learning in diverse fields of biotechnology is hampered by the inability of students and specialists in each of the constituent areas—microbiology, chemical engineering, chemistry, biochemistry—to understand each other's language. This is because each lacks the basic knowledge required to understand and interpret even the most fundamental of concepts under discussion. Due to the different language, jargons and definitions used, crossing the interdisciplinary boundaries often becomes difficult.

Keeping this in mind, in the forthcoming chapters of this book, an effort has been made to introduce the reader to the multidisciplinary subject of biotechnology by exposing him to its vast applications (commercially successful or scientific developments). Stress is given on citing numerous examples in each field of application and indirectly making the reader familiar with the mixed language. It will not be a surprise if the reader (from any discipline) is fascinated so much as to start thinking, speaking and applying his mind in biotechnological language.

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BIOLOGY-BIOTECHNOLOGY-BIOTICS

Supremacy of man over the other members of the living kingdom lies in the evolutionary state reached by human beings over the millions of years. Man has made progress by observing nature, studying its basic principles, making applications of information obtained, correcting the mistakes and again trying to achieve better control. Naturally, while doing this, he developed knowledge about facts basic to his life. So he collected information through observations about the structure, organisation, function, heredity, growth, reproduction etc., which are common to the different life forms, although their nature and complexity vary. This information collectively can be referred to as the basic life sciences—Fundamental biosciences—which consider the physical, mechanical and chemical phenomena highly related to the existence of life but also account for the relationship between life and matter in the form of vitalism.

Fundamental biosciences have contributed a lot to the progress of human beings. Knowledge in the fundamental biosciences today is almost 20 times of what it was in 1900 and 6 times of what it was in 1930 and perhaps by the 21st century, there may be 100 times information required to be studied as fundamental bioscience as compared to what it was there at the beginning of this century. Man, however, was never satisfied with only the fundamental facts, concepts and principles understood through fundamental biosciences and it was inevitable on his part to make useful applications of the

information obtained. This process did not start separately or recently but has been there since ancient times when man learnt to grow proper varieties of crops and achieved the skills of making bread, fermented milk products, wine and vinegar, etc. during the long years. And thus the utilitarian aspect of living system developed into applied biosciences. Through applied biosciences, man showed the ability to improve plant productivity, better animal products, producing chemicals and drugs for disease control etc.

Along with the advances in fundamental and applied bioscience, developments in other sciences has resulted in specialised studies in individual disciplines such as biochemistry, microbiology, genetics and molecular biology as also engineering and other technologies. The relationship between these disciplines has become extremely close and has come in the form of biotechnology which is directed towards harvesting economic benefits.

Nature (Life with its surroundings)
↓ development
Understanding (of basic principles)
↓ development
Using, exploiting, spoiling (application of information)
↓ development
Understanding
↓ development
Remaking, improving, controlling (technological success)

Basic Life Science (Fundamental Bioscience)	*Applied Life Science (Applied Bioscience)*	*Biotechnology*
Structure	Growth on a large scale	Microbes as
Organisation	Mutations	workhouses
Function	Breeding	Minicells,
Heredity	Improving	Membrane
Reproduction	characters	Bioreactors
Energetics	Producing useful	Gene Manipulation
Metabolism	Chemicals	(Genetic engineering)
Identification		New strains
Classification		Pollution Control
Ecological relationship		Crossing boundaries
Evolution		
Diversity		
Balance in Nature		

When it was found that there was a lot of physics involved in the study of biology, a separate branch was developed called biophysics, similar on lines with biochemistry and then the application of mathematical principles on a large scale to biological observations resulted in a new field of a study called biometics. In the early fifties and more recently, similar fields of interest have been developed by the cross-fertilization of biology with other disciplines and thus Bionics, Bioelectronics were born. In the research field, it may prove fruitful to bring about the convergence of several disciplines (as well as automatic engineering, data processing, microelectronics with biology). A new concept dealing with such various fields as computers in biology, microelectronics and other devices, biochemical reactions in automatic machines and analytical apparatus, electronic properties of molecules to make transducers, probes, chips, enzymes and micromachines and microrobots, new biomaterials, is born. These hybrid new research fields at the heart of biotechnology are going to have a great significance for at least the next fifty years. By analogy with other new fields related to computer science such as telematics, robotics, Joel De Rosnay has proposed the word 'Biotics.'

'Biotics' is a new field of research, development and applications resulting from the fusion of several disciplines and particularly, solid state physics, microelectronics, organic chemistry, electrochemistry, molecular biology and through the extensive use of information technology (data processing, automation, robots) in all areas of biology.

Such a fusion is possible because of the following properties of biological and information system:

(1) Genetic code, control of gene expression, receptors, peptide hormones, histocompatibility antigens represent some of the elements (methods) of communication and network regulation of the living system. This understanding and terminologies are having a simily with that in the information science and engineering. Therefore, bridges can be built between the biological system and these sciences.

(2) Biological informational macromolecules (DNA, proteins) are prone to the processing and memorisation of data by computers. Information in macromolecules is like the 'Printed text on computers', linear additions, identification and synthesis involved.

(3) Our ability to handle molecules one by one and put them in any possible order brings biology and information science really close. Before the advent of micronengineering techniques, we were able to handle molecules statistically and not as independent units.

Molecular machines now can be assembled by working from the microlevel to the macrolevel.

Thus biosensors are already in wide use (an example of electronics interacting with biological entities) and biomolecular computers are not a very distant reality but will need only 1-2 decades' wait to play wonders.

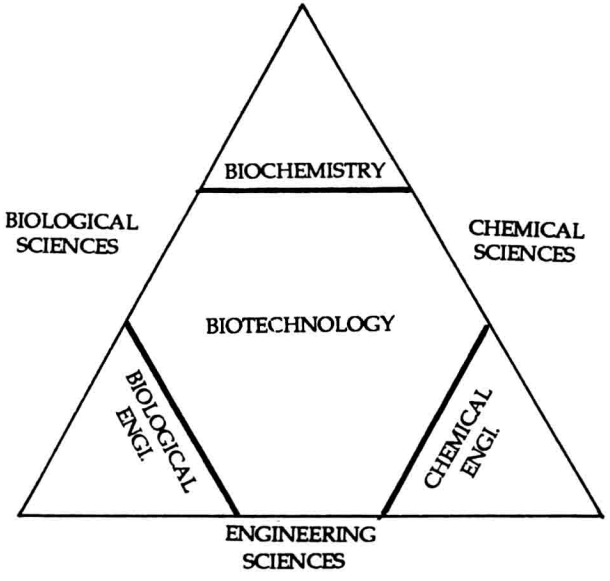

Fig. 2.1 Multifacets (Multidisciplinary nature) of Biotechnology.

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