

Biotechnology

Textbook for Class XI



11150

विद्यया ऽ मृतमश्नुते



एन सी ई आर टी
NCERT

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

11150 – BIOTECHNOLOGY

Textbook for Class XI

ISBN 978-93-5292-188-1

First Edition

October 2019 Ashwina 1941

Reprinted

August 2021 Shravana 1943

March 2022 Phalguna 1943

February 2025 Phalguna 1946

PD 3T RSP

© National Council of Educational
Research and Training, 2019

₹ 330.00

Printed on 80 GSM paper with NCERT
watermark

Published at the Publication Division
by the Secretary, National Council of
Educational Research and Training,
Sri Aurobindo Marg, New Delhi 110 016
and printed at Indian Printing Works,
E-4, Jhandewalan Ext., Rani Jhansi
Road, New Delhi - 110 055

ALL RIGHTS RESERVED

- ❑ No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior permission of the publisher.
- ❑ This book is sold subject to the condition that it shall not, by way of trade, be lent, re-sold, hired out or otherwise disposed off without the publisher's consent, in any form of binding or cover other than that in which it is published.
- ❑ The correct price of this publication is the price printed on this page. Any revised price indicated by a rubber stamp or by a sticker or by any other means is incorrect and should be unacceptable.

OFFICES OF THE PUBLICATION

DIVISION, NCERT

NCERT Campus
Sri Aurobindo Marg
New Delhi 110 016 Phone : 011-26562708

108, 100 Feet Road
Hosdakere Halli Extension
Banashankari III Stage
Bengaluru 560 085 Phone : 080-26725740

Navjivan Trust Building
P.O. Navjivan
Ahmedabad 380 014 Phone : 079-27541446

CWC Campus
Opp. Dhankal Bus Stop
Panihati
Kolkata 700 114 Phone : 033-25530454

CWC Complex
Maligaon
Guwahati 781 021 Phone : 0361-2674869

Publication Team

Head, Publication Division : *M.V. Srinivasan*

Chief Editor : *Bijnan Sutar*

Chief Production Officer (In charge) : *Jahan Lal*

Chief Business Manager : *Amitabh Kumar*

Editor : *Bijnan Sutar*

Production Assistant : *Om Prakash*

Cover and Layout

DTP Cell, DESM

Foreword

Biotechnology is comparatively a newer discipline as compared to Biology, Chemistry or Microbiology. It has emerged as a new subject to be taught in schools and colleges in the last two–three decades. As the name indicates, Biotechnology fundamentally deals with the application of laws and principles that govern and control the processes and phenomenon in living organisms.

Considering the fact that Biotechnology has a potential to provide solutions to many of the diverse problems that our society is facing right from protection and conservation of environment to treatment of diseases; production of alcoholic beverages to many humulin pharmaceutical products (one such example is monoclonal antibodies used for the treatment and diagnosis of diabetes); development of drought and disease resistant crop varieties in agriculture to genetically modified crops; understanding genetic bases of many of the phenomena happening in organisms to deciphering the whole genome and such others. All these have created new vistas and wider opportunities with tremendous potential.

This emerging area has not only helped in providing solutions to many problems and answers to a number of queries related to fundamentals of the processes and phenomena of living organisms, but, it has also opened the gate of interdisciplinary collaborations in newer areas. Today's Biotechnology or even Biology for that matter cannot be completely understood without the understanding of Physics and Chemistry. Similarly, generations of enormous data and its interpretation has opened up opportunities in yet another area called Bioinformatics, which largely depends on computer based applications, softwares and algorithms. This has a potential of even providing tailor made diagnosis and treatment of diseases and prediction of a person's possible suffering of diseases in future.

However, considering the fact that the present course is an entry level one, this book mainly focuses on understanding the fundamental concepts. Focus has also been given on problem solving skills by providing opportunities for hands-on activities and experiments in laboratories on one hand, and working on bioinformatics databases on the other.

Last but not the least, as an organisation committed to systemic reforms and continuous improvement in the quality of its teaching-learning products, NCERT has always welcomed comments and suggestions which enables us to improve the quality of materials. Valuable comments and suggestions on the book will also help NCERT to improve the content of the textbook.

New Delhi
November 2018

Director
National Council of Educational
Research and Training

© NCERT
not to be republished

Preface

Quite recently, in the last two-three decades specialised disciplines like Biotechnology, Computer Science, Information Practices, etc., have emerged as priority areas in school education and these have been introduced at the higher secondary stage. This stage is challenging because of the transition from general to discipline-based curriculum. The higher secondary stage is also a connecting link between school education and higher and technical education. Therefore, syllabus at this stage needs to have appropriate rigour and depth while remaining mindful of the comprehension level of the learners. Further, the textbook need not be heavily loaded with content.

Biotechnology, as the name suggests, is an applied discipline which has potential to impact various facets. On one hand it has provided solutions to many health and medicine related problems, while on the other it has provided opportunities to explore newer areas like genomics, transcriptomics, proteomics, etc. These areas have implications to improve the quality of life besides solving many problems on various fronts like treatment of diseases, environmental protection and conservation, and understanding the process of evolution of life on earth, etc.

As an applied area related to molecular biology and biotechnology, Bioinformatics has also become a popular discipline due to generation of enormous amount of data in the area of genome biology. Needless to mention that about 15 years back we have seen the publication of draft human genome as an outcome of globally collaborated project called, 'Human Genome Project'.

Students take up Biotechnology with an aim of pursuing a career in molecular biology, molecular medicine, genome biology and various production industries related to biotechnology and molecular biology. Therefore, the course content of the subject must address all areas in which the subject has an implication. At the same time, it is also to be considered that the course must also make a foundation for higher and technical education. An attempt has been made in this direction to ensure that there is a balance between appropriateness and prospective need.

The course for Class XI has been divided into five units with 12 chapters. Unit I provides an introduction to the subject — its background and application in various areas. Unit II, has four chapters with details to understanding of cells, its biomolecules including enzyme and cellular processes. Three chapters of Unit III will be helpful in developing the understanding of fundamentals of genetics, genetic material, mechanisms and processes related to DNA and RNA, and certain abnormalities in human beings especially related to chromosomal and genetic mechanisms. Unit IV, has three chapters, on quantitative biology, bioinformatics and programming in biology with application. The last unit of the book acquaints learners in the understanding of various tools and techniques used in the area of Biotechnology. An attempt has been made that the book provides a lucid reading to students and teachers so that it can effectively transact the concepts mentioned.

I take this opportunity to place on record appreciation for U. N. Dwivedi, *Professor* Department of Biochemistry and Pro-Vice Chancellor of University of Lucknow, for leading the activities in the book as well as for his guidance and motivation to the development team. Thanks are due to the authors and reviewers for their valuable contribution.

Comments and suggestions towards the improvement of this book are welcome.

Dinesh Kumar
Professor and Head
Department of Education in
Science and Mathematics

© NCERT
not to be republished

Textbook Development Committee

CHAIRPERSON

U. N. Dwivedi, *Professor*, Department of Biochemistry, University of Lucknow, Lucknow

MEMBERS

Amit Dinda, *Professor*, Department of Pathology, All India Institute of Medical Sciences, Delhi

Animesh Kumar Mohapatra, *Professor*, Regional Institute of Education, Bhubaneswar

Binay Panda, *Director*, Ganit Labs Foundation, Bio-IT Centre, Institute of Bioinformatics and Applied Biotechnology, Bengaluru

Indrakant K. Singh, *Assistant Professor*, Department of Zoology, Deshbandhu College, University of Delhi, Delhi

Kusum Yadav, *Assistant Professor*, Department of Biochemistry, University of Lucknow, Lucknow

Manoj K. Sharma, *Assistant Professor*, School of Biotechnology, Jawaharlal Nehru University, Delhi

Pawan K. Dhar, *Professor*, School of Biotechnology, Jawaharlal Nehru University, Delhi

Pushp Lata Verma, *Associate Professor*, Department of Education in Science and Mathematics, NCERT

Sunita Farkya, *Professor*, Department of Education in Science and Mathematics, NCERT

MEMBER CO-ORDINATOR

Dinesh Kumar, *Professor and Head*, Department of Education in Science and Mathematics, NCERT

Acknowledgements

National Council of Educational Research and Training (NCERT) gratefully acknowledges the contribution of the individuals and organisations involved in the development of the Biotechnology textbook for Class XI. The Council is grateful to G. B. N. Chainy, *Professor*, Department of Zoology and Biotechnology, Utkal University, Odisha; Rupesh Chaturvedi, *Professor*, School of Biotechnology, Jawaharlal Nehru University, Delhi; Poonam Sharma, *Assistant Professor*, Gargi College, University of Delhi, Delhi; C. V. Shimray, *Assistant Professor*, Department of Education in Science and Mathematics, NCERT and Veda Prakash Pandey, *DST-SERB Young Scientist*, Department of Plant Biotechnology, Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow for their contribution in the review of the manuscripts.

The Council is also thankful to Indrakant K. Singh, *Assistant Professor*, Deshbandhu College, University of Delhi, Delhi for providing pictures of electrophoresis apparatus and vertical section of maize and wheat leaf from his Molecular Biology Research lab.

NCERT is highly thankful to Archana Thakur, *Deputy Director*, Central Board of Secondary Education, Delhi; Shakun Singh, *PGT*, Bhatnagar International School, Vasant Kunj, Delhi; Madhumati Bhaskara, *PGT*, G.D. Goenka Public School, Vasant Kunj, Delhi; Anjulika Joshi, *PGT*, Mount Carmel School, Anand Niketan, Delhi; Payal Priyadarshini, *PGT*, Kendriya Vidyalaya, Delhi Cantt-3, Delhi; Pratibha Sharma, *PGT*, Kendriya Vidyalaya, JNU, Delhi and Ambika Nagrath, *PGT*, Army Public School, Dhaula Kuan, Delhi for their valuable suggestions.

Valuable suggestions and comments given by Ravindra Kumar Parashar, *Professor*, Department of Education in Science and Mathematics, NCERT and Alka Mehrotra, *Professor*, Department of Education in Science and Mathematics, NCERT especially on thermodynamics and biomolecules chapters have helped in improving the content of the book.

The Council also acknowledges the academic contributions of Priyal Sharma, *Junior Project Fellow*, in finalising the manuscript. Contributions of Suman Prajapati, *Graphic Designer* and Preeti Dhiman, *DTP Operator* for typesetting are also acknowledged. Without their effort it would not have been possible to bring out the manuscript. Cooperation from Rajendra Singh, *Assistant Program Coordinator*, and his staff for their help in organising workshops and office logistics for the same is especially thanked.

The efforts of Soumma Chandra, *Assistant Editor* (Contractual), C. Thangminlal Dounge, *Editorial Assistant* (Contractual), Chanchal Chouhan, *Proof Reader* (Contractual), and Naresh Kumar, *DTP Operator* (Contractual), of the Publication Division, NCERT in bringing out the first edition of this book is also highly appreciated.

Contents

Foreword	iii
Preface	v
Unit I: An Introduction to Biotechnology	1-22
Chapter 1: Introduction	3
1.1 Historical Perspectives	4
1.2 Applications of Modern Biotechnology	8
1.3 Biotechnology in India: Academic Prospects and Industrial Scenario	16
Unit II: Cell Organelles and Biomolecules	23-144
Chapter 2: Cellular Organelles	25
2.1 Plasma Membrane	26
2.2 Cell Wall	29
2.3 Endomembrane System	31
2.4 Mitochondria	36
2.5 Plastids	37
2.6 Ribosomes	38
2.7 Microbodies	39
2.8 Cytoskeleton	40
2.9 Cilia and Flagella	41
2.10 Centrosome and Centrioles	42
2.11 Nucleus	43
2.12 Chromosome	45
Chapter 3: Biomolecules	50
3.1 Carbohydrates	50
3.2 Fatty Acids and Lipids	59
3.3 Amino Acids	63
3.4 Protein Structure	67
3.5 Nucleic Acids	75
Chapter 4: Enzymes and Bioenergetics	85
4.1 Enzymes: Classification and Mode of Action	85
4.2 Brief Introduction to Bioenergetics	96

Chapter 5: Cellular Processes	103
5.1 Cell Signaling	103
5.2 Metabolic Pathways	104
5.3 Cell Cycle	126
5.4 Programmed Cell Death (Apoptosis)	135
5.5 Cell Differentiation	136
5.6 Cell Migration	139
Unit III: Genetic Principles and Molecular Processes	145-232
Chapter 6: Basic Principles of Inheritance	147
6.1 Introduction to Inheritance	147
6.2 Linkage and Crossing Over	153
6.3 Recombination	156
6.4 Sex-linked Inheritance	158
6.5 Extrachromosomal Inheritance	159
6.6 Polyploidy	160
6.7 Reverse Genetics	161
Chapter 7: Basic Processes	166
7.1 DNA as the Genetic Material	166
7.2 Prokaryotic and Eukaryotic Gene Organisation	171
7.3 DNA Replication	175
7.4 Gene Expression	184
7.5 Genetic Code	191
7.6 Translation	193
7.7 Gene Mutation	199
7.8 DNA Repair	205
7.9 Regulation of Gene Expression	208
Chapter 8: Genetic Disorder	217
8.1 Chromosomal Abnormalities and Syndromes	217
8.2 Monogenic Disorders and Pedigree Mapping	222
8.3 Polygenic Disorders	227

Unit IV: Quantitative Biology and Bioinformatics	233-278
Chapter 9: Introduction to Bioinformatics	235
9.1 The Utility of Basic Mathematical and Statistical Concepts to Understand Biological Systems and Processes	235
9.2 Introduction	239
9.3 Biological Databases	244
9.4 Genome Informatics	247
9.5 Role of Artificial Intelligence (AI) in Future	253
Chapter 10: Protein Informatics and Cheminformatics	256
10.1 Protein Informatics	256
10.2 Cheminformatics	261
Chapter 11: Programming and Systems Biology	270
11.1 Programming in Biology	270
11.2 Systems Biology	272
Unit V: Tools and Techniques: Basic Concepts	279-316
Chapter 12: Tools and Techniques	281
12.1 Microscopy	281
12.2 Centrifugation	286
12.3 Electrophoresis	287
12.4 Enzyme-linked Immunosorbent Assay (ELISA)	291
12.5 Chromatography	294
12.6 Spectroscopy	297
12.7 Mass Spectrometry	301
12.8 Fluorescence in Situ Hybridisation (FISH)	301
12.9 DNA Sequencing	303
12.10 DNA Microarray	308
12.11 Flow Cytometry	311

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a ¹**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the ²[unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2. for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2. for "Unity of the Nation" (w.e.f. 3.1.1977)