

# 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 Shrawana 1943

March 2022 Phalguna 1943

**PD 20T 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 : *Anup Kumar Rajput*

Chief Editor : *Shveta Uppal*

Chief Production Officer : *Arun Chitkara*

Chief Business Manager : *Vipin Dewan*

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

# 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 Nagratan, *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 Dounghel, *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 Endoplasmic Reticulum	32
2.4 Golgi Apparatus	34
2.5 Lysosomes	35
2.6 Vacuoles	35
2.7 Mitochondria	36
2.8 Plastids	37
2.9 Ribosomes	39
2.10 Microbodies	40
2.11 Cytoskeleton	40
2.12 Cilia and Flagella	41
2.13 Centrosome and Centrioles	42
2.14 Nucleus	43
2.15 Nucleolus	45
2.16 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

<b>Chapter 4: Enzymes and Bioenergetics</b>	<b>85</b>
4.1 Enzymes: Classification and Mode of Action	85
4.2 Brief Introduction to Bioenergetics	96
<b>Chapter 5: Cellular Processes</b>	<b>103</b>
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
<b>Unit III: Genetic Principles and Molecular Processes</b>	<b>145-232</b>
<b>Chapter 6: Basic Principles of Inheritance</b>	<b>147</b>
6.1 Introduction to Inheritance	147
6.2 Linkage and Crossing Over	153
6.3 Sex-linked Inheritance	156
6.4 Extrachromosomal Inheritance	157
6.5 Polyploidy	158
6.6 Reverse Genetics	159
<b>Chapter 7: Basic Processes</b>	<b>164</b>
7.1 DNA as the Genetic Material	164
7.2 Prokaryotic and Eukaryotic Gene Organisation	169
7.3 DNA Replication	173
7.4 Gene Expression	182
7.5 Genetic Code	189
7.6 Translation	191
7.7 Gene Mutation	197
7.8 DNA Repair	202
7.9 Recombination	206
7.10 Regulation of Gene Expression	208
<b>Chapter 8: Genetic Disorder</b>	<b>217</b>
8.1 Chromosomal Abnormalities and Syndromes	217
8.2 Monogenic Disorders and Pedigree Mapping	222
8.3 Polygenic Disorders	227

<b>Unit IV: Quantitative Biology and Bioinformatics</b>	<b>233-284</b>
<b>Chapter 9: Introduction to Bioinformatics</b>	<b>235</b>
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
<b>Chapter 10: Protein Informatics and Cheminformatics</b>	<b>260</b>
10.1 Protein Informatics	260
10.2 Cheminformatics	266
<b>Chapter 11: Programming and Systems Biology</b>	<b>276</b>
11.1 Programming in Biology	276
11.2 Systems Biology	278
<b>Unit V: Tools and Technologies: Basic Concepts</b>	<b>285-323</b>
<b>Chapter 12: Tools and Technologies</b>	<b>287</b>
12.1 Microscopy	287
12.2 Centrifugation	292
12.3 Electrophoresis	294
12.4 Enzyme-linked Immunosorbent Assay (ELISA)	297
12.5 Chromatography	300
12.6 Spectroscopy	303
12.7 Mass Spectrometry	307
12.8 Fluorescence in Situ Hybridisation (FISH)	307
12.9 DNA Sequencing	309
12.10 DNA Microarray	314
12.11 Flow Cytometry	317



**Empowerment of Girl Child, Responsibility of All**