

NINTH EDITION

PART 1

Life Sciences

Fundamentals and Practice

PRANAV KUMAR USHA MINA

Life Sciences

Fundamentals and Practice

Part-1

Ninth edition

PRANAV KUMAR

Former faculty,
Department of Biotechnology,
Jamia Millia Islamia (JMI),
New Delhi, India

USHA MINA

Professor,
School of Environmental Sciences,
Jawaharlal Nehru University (JNU),
New Delhi, India



Pathfinder Publication

New Delhi, India



Pranav Kumar

Former faculty,
Department of Biotechnology,
Jamia Millia Islamia (JMI),
New Delhi, India



Usha Mina

Professor,
School of Environmental Sciences,
Jawaharlal Nehru University (JNU),
New Delhi, India

Life Sciences: Fundamentals and Practice

Ninth edition

ISBN: 978-81-956333-4-0 (paperback)

Copyright © 2024 by Pathfinder Publication, all rights reserved.

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

No part of this book may be reproduced by any mechanical, photographic, or electronic process, or in the form of a phonographic recording, nor it may be stored in a retrieval system, transmitted, or otherwise copied for public or private use, without written permission from the publisher.

Publisher : Pathfinder Publication

Illustration and layout : Pradeep Verma

Cover design : Pradeep Verma

Marketing director : Arun Kumar

Production coordinator : Murari Kumar Singh

Pathfinder Publication

A unit of Pathfinder Academy Private Limited, New Delhi, India.

pathfinderpublication.in

Contents

Chapter 1

Biomolecules and Catalysis

1.1	Amino acids and Proteins	2	1.6.2	Z-DNA	64
1.1.1	Absolute configuration	5	1.6.3	Triplex DNA	65
1.1.2	Optical activity	6	1.6.4	G-quadruplex	66
1.1.3	Standard and non-standard amino acids	7	1.6.5	Stability of the dsDNA helix	67
1.1.4	Titration of amino acids	11	1.6.6	DNA denaturation	67
1.1.5	Peptide and polypeptide	17	1.6.7	Quantification of nucleic acids	69
1.1.6	Peptide bond	18	1.6.8	Supercoiled forms of DNA	70
1.1.7	Protein structure	21	1.6.9	DNA: A genetic material	73
1.1.8	Denaturation of proteins	28	1.7	RNA	75
1.1.9	Solubilities of proteins	28	1.7.1	Alkaline hydrolysis of RNA	76
1.1.10	Simple and conjugated proteins	29	1.7.2	RNA World hypothesis	77
1.2	Fibrous and globular proteins	30	1.7.3	RNA as genetic material	77
1.2.1	Collagen	31	1.8	Carbohydrates	78
1.2.2	Elastin	33	1.8.1	Monosaccharides	78
1.2.3	Keratins	34	1.8.2	Epimers	79
1.2.4	Myoglobin	34	1.8.3	Cyclic forms	81
1.2.5	Hemoglobin	36	1.8.4	Derivatives of monosaccharide	83
1.2.6	Behavior of allosteric proteins	42	1.8.5	Disaccharides and glycosidic bond	85
1.3	Protein folding	43	1.8.6	Polysaccharides	86
1.3.1	Molecular chaperones	45	1.8.7	Glycoproteins	89
1.3.2	Amyloid	46	1.8.8	Reducing and non-reducing sugar	89
1.3.3	Ubiquitin-mediated protein degradation	47	1.9	Lipids	90
1.3.4	N-end rule	49	1.9.1	Fatty acids	90
1.4	Protein sequencing and assays	50	1.9.2	Triacylglycerol and Wax	92
1.5	Nucleic acids	56	1.9.3	Phospholipids	93
1.5.1	Nucleotides	56	1.9.4	Glycolipids	94
1.5.2	Chargaff's rules	60	1.9.5	Steroid	95
1.6	Structure of dsDNA	61	1.9.6	Eicosanoid	95
1.6.1	B-DNA	62	1.9.7	Plasma lipoproteins	98

1.10	Vitamins	98		
1.10.1	Water-soluble vitamins	98		
1.10.2	Fat-soluble vitamins	103		
1.11	Reactive oxygen species and antioxidants	105		
1.12	Enzymes	107		
1.12.1	Naming and classification of enzymes	108		
1.12.2	How enzymes operate?	109		
1.12.3	Catalytic strategies	111		
1.12.4	Enzyme kinetics	112		
1.12.5	Enzyme inhibition	120		
1.12.6	Regulatory enzymes	125		
1.12.7	Isozymes	127		
1.12.8	Zymogen	128		
1.12.9	Nucleic acids as catalysts	128		
1.12.10	Abzyme	129		
1.12.11	Examples of enzymatic reactions	130		
			2.1.17	Warburg effect
			2.1.18	Respiratory substrate and respiratory quotient
			2.2	Glyoxylate cycle
			2.3	Pentose phosphate pathway
			2.4	Entner-Doudoroff pathway
			2.5	Photosynthesis
			2.5.1	Photosynthetic pigments
			2.5.2	Absorption and action spectra
			2.5.3	Fate of light energy absorbed by photosynthetic pigments
			2.5.4	Concept of photosynthetic unit
			2.5.5	Hill reaction
			2.5.6	Oxygenic & Anoxygenic photosynthesis
			2.5.7	Concept of pigment system
			2.5.8	Photosynthesis in green plants
			2.5.9	Light reactions
			2.5.10	Carbon-fixation cycle
			2.5.11	Starch and sucrose synthesis
			2.6	Photorespiration
			2.6.1	C ₄ cycle
			2.6.2	CAM pathway
			2.7	Carbohydrate metabolism
			2.7.1	Gluconeogenesis
			2.7.2	Glycogen metabolism
			2.8	Lipid metabolism
			2.8.1	Synthesis & storage of triacylglycerols
			2.8.2	Biosynthesis of fatty acids
			2.8.3	Fatty acid oxidation
			2.8.4	Biosynthesis of cholesterol
			2.8.5	Steroid hormones and Bile acids
			2.9	Amino acid metabolism
			2.9.1	Amino acid synthesis
			2.9.2	Amino acid catabolism
			2.9.3	Molecules derived from amino acids
			2.10	Nucleotide metabolism
			2.10.1	Nucleotide synthesis
			2.10.2	Nucleotide degradation

Chapter 2

Bioenergetics and Metabolism

2.1	Respiration	158		
2.1.1	Aerobic respiration	159		
2.1.2	Glycolysis	160		
2.1.3	Pyruvate oxidation	165		
2.1.4	Citric acid cycle	167		
2.1.5	Anaplerotic reaction	170		
2.1.6	Oxidative phosphorylation	171		
2.1.7	Inhibitors of electron transport	175		
2.1.8	Electrochemical proton gradient	176		
2.1.9	Chemiosmotic theory	178		
2.1.10	ATP synthase	179		
2.1.11	Uncoupling agents and ionophores	181		
2.1.12	ATP-ADP exchange across the inner mitochondrial membrane	182		
2.1.13	Shuttle systems	183		
2.1.14	P/O ratio	184		
2.1.15	Fermentation	185		
2.1.16	Pasteur effect	187		

Chapter 3

Cell Structure and Functions

- 3.1 What is a cell? 274
- 3.2 Plasma membrane 275
 - 3.2.1 ABO blood group 285
 - 3.2.2 Transport across plasma membrane 288
- 3.3 Membrane potential 296
- 3.4 Transport of macromolecules across plasma membrane 306
 - 3.4.1 Endocytosis 306
 - 3.4.2 Fate of receptor 311
 - 3.4.3 Exocytosis 312
- 3.5 Ribosomes 313
 - 3.5.1 Protein targeting and translocation 315
- 3.6 Endoplasmic reticulum 316
 - 3.6.1 Transport from cytosol to ER 321
 - 3.6.2 Transport from ER to *cis*-Golgi 326
- 3.7 Golgi complex 328
 - 3.7.1 Transport of proteins through cisternae 330
 - 3.7.2 Transport from the TGN to lysosomes 330
- 3.8 Membrane fusion 332
- 3.9 Lysosome 334
- 3.10 Vacuoles 336
- 3.11 Mitochondria 336
- 3.12 Plastids 340
- 3.13 Peroxisome 342
- 3.14 Nucleus 344
- 3.15 Cytoskeleton 348
 - 3.15.1 Microtubules 348
 - 3.15.2 Microtubule-based motor proteins: Kinesins and Dyneins 351
 - 3.15.3 Cilia and Flagella 352
 - 3.15.4 Centriole 354
 - 3.15.5 Actin filament 355
 - 3.15.6 Myosin 358
 - 3.15.7 Muscle contraction 359
 - 3.15.8 Intermediate filaments 363
- 3.16 Cell junctions 364
- 3.17 Cell adhesion molecules 367
- 3.18 Extracellular matrix of animals 369
- 3.19 Plant cell wall 370
- 3.20 Cell signaling 372
 - 3.20.1 Signal molecules 372
 - 3.20.2 Receptors 373
 - 3.20.3 GPCR and G-proteins 376
 - 3.20.4 Ion channel-linked receptors 385
 - 3.20.5 Enzyme-linked receptors 386
 - 3.20.6 Chemotaxis in bacteria 395
 - 3.20.7 Quorum sensing 397
- 3.21 Cell Cycle 399
 - 3.21.1 Role of Rb in cell cycle regulation 410
 - 3.21.2 Role of p53 in cell cycle regulation 411
 - 3.21.3 Replicative senescence 413
- 3.22 Mechanics of cell division 414
 - 3.22.1 Mitosis 414
 - 3.22.2 Meiosis 421
 - 3.22.3 Nondisjunction and aneuploidy 426
- 3.23 Apoptosis 429
- 3.24 Cancer 433

Chapter 4

Prokaryotes and Viruses

- 4.1 Phylogenetic overview 448
- 4.2 Structure of bacterial cell 449
- 4.3 Bacterial genome 461
- 4.4 Bacterial nutrition 465
 - 4.4.1 Culture media 466
 - 4.4.2 Bacterial growth 468
- 4.5 Horizontal gene transfer and recombination 471
 - 4.5.1 Transformation 472
 - 4.5.2 Transduction 473
 - 4.5.3 Conjugation 477
- 4.6 Mapping of chromosomal genes 480
- 4.7 Bacterial taxonomy 485
- 4.8 General features of bacterial groups 486

4.9	Archaeobacteria	488	5.12	Monoclonal antibodies and Hybridoma technology	577
4.10	Bacterial toxins	490	5.13	T cells and cell-mediated immunity	579
4.11	Control of microbial growth	491	5.13.1	Superantigens	592
4.12	Viruses	495	5.14	The complement system	592
4.12.1	Bacteriophages (Bacterial virus)	497	5.15	Hypersensitivity	596
4.12.2	Life cycle of bacteriophage	498	5.16	Autoimmunity	598
4.12.3	Plaques assay	501	5.17	Transplantation	598
4.12.4	Genetic analysis of phage	504	5.18	Immunodeficiency diseases	601
4.12.5	Animal viruses	507	5.19	Failures of host defense mechanisms	601
4.12.6	Plant viruses	517	5.20	Vaccines	603
4.13	Prions and Viroids	518			
4.13.1	Bacterial and viral diseases	520			

Chapter 5

Immunology

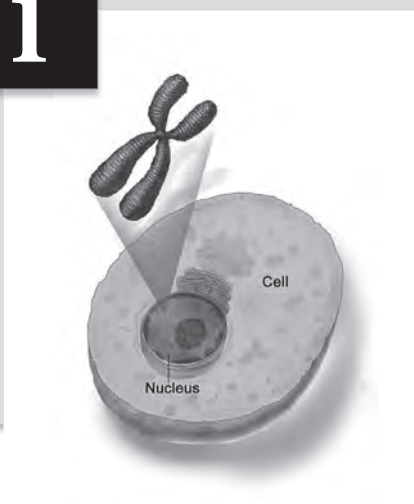
5.1	Innate immunity	523
5.2	Adaptive immunity	529
5.3	Cells of the immune system	531
5.3.1	Common lymphoid progenitor	531
5.3.2	Common myeloid progenitor	533
5.4	Organs involved in the adaptive immune response	535
5.4.1	Primary lymphoid organs	535
5.4.2	Secondary lymphoid organs/tissues	536
5.5	Antigens	537
5.6	Major histocompatibility complex	540
5.6.1	MHC and antigen presentation	542
5.6.2	Antigen processing and presentation	543
5.7	Immunoglobulins: Structure and function	546
5.7.1	Basic structure of antibody molecule	546
5.7.2	Different classes of antibody	549
5.7.3	Antigenic determinants on antibodies	551
5.8	Organization and expression of Ig genes	552
5.9	Generation of antibody diversity	558
5.10	B cell maturation and activation	560
5.11	Kinetics of the antibody response	573
5.11.1	Humoral immune response	575

Chapter 6

Diversity of Life

6.1	Taxonomy	611
6.1.1	Nomenclature	612
6.1.2	Classification	612
6.1.3	Biological species concept	613
6.1.4	Phenetics and cladistics approaches of classification	614
6.2	Five-kingdom system	620
6.3	Protists	622
6.3.1	Protozoan protists	622
6.3.2	Photosynthetic protists	623
6.3.3	Slime mold	624
6.3.4	Oomycetes	625
6.4	Fungi	625
6.4.1	Mycorrhiza	627
6.4.2	Lichens	628
6.5	Plantae	628
6.5.1	Plant life cycle	629
6.5.2	Algae	631
6.5.3	Life cycle of land plants	633
6.5.4	Bryophytes	634
6.5.5	Pteridophytes	635
6.5.6	Gymnosperm	638
6.5.7	Angiosperms	638

6.6	Animalia	644	7.7.2	Population growth	703
6.7	Animal's classification	652	7.7.3	Life table	707
6.7.1	Phylum Porifera	652	7.7.4	Population regulation	708
6.7.2	Phylum Cnidaria (Coelenterata)	652	7.7.5	Life history	710
6.7.3	Phylum Platyhelminthes (Flatworms)	653	7.8	Community ecology	712
6.7.4	Phylum Aschelminthes	653	7.8.1	Community structure	712
6.7.5	Phylum Annelida	654	7.8.2	Species composition	712
6.7.6	Phylum Mollusca	655	7.8.3	Species diversity	713
6.7.7	Phylum Arthropoda	655	7.8.4	Diversity index	715
6.7.8	Phylum Echinodermata	656	7.8.5	Disturbance and species diversity	717
6.7.9	Phylum Hemichordata	656	7.8.6	Diversity-Stability-Complexity relationships	717
6.7.10	Phylum Chordata	656	7.8.7	Community gradient and boundaries	719
Chapter 7					
Ecology					
7.1	The Environment	665	7.9	Island biogeography	720
7.1.1	Physical environment	665	7.10	Ecological interdependence and interactions	721
7.1.2	Adaptation to the physical environment	670	7.11	Lotka-Volterra model	726
7.2	Shelford's law of tolerance	672	7.12	Ecological niche	732
7.3	Ecosystem	673	7.13	Effect of competition	734
7.3.1	Ecosystem components	673	7.14	Ecological succession	737
7.3.2	Productivity	674	7.14.1	Pattern of succession	737
7.3.3	Energy flow	677	7.14.2	Types of ecological succession	739
7.3.4	Food chains	679	7.14.3	Mechanism of succession	740
7.3.5	Ecological efficiencies	681	7.14.4	Models of succession	741
7.3.6	Ecological pyramid	683	7.15	Biodiversity	743
7.3.7	Nutrient cycling	684	7.15.1	Levels of biodiversity	743
7.3.8	Decomposition	686	7.15.2	Gradients and Magnitude of biodiversity	743
7.4	Ecosystem services	686	7.15.3	Uses of biodiversity	744
7.4.1	Control of trophic structure: top-down versus bottom-up control	687	7.15.4	Threats to biodiversity	745
7.5	Types of Ecosystems	688	7.15.5	Extinction of species	747
7.5.1	Aquatic ecosystem	689	7.15.6	IUCN Red List categories and criteria	748
7.5.2	Terrestrial ecosystem	695	7.15.7	Conservation of biodiversity	749
7.6	Biomes	697	7.16	Behavioural ecology	751
7.7	Population ecology	700	7.16.1	Mating behaviour	755
7.7.1	Population characteristics	700	Index 763		



Biomolecules and Catalysis

Learning objective

- | | |
|-----------------------------------|-----------------------------------------------|
| 1.1 Amino acids and Proteins | 1.7 RNA |
| 1.2 Fibrous and globular proteins | 1.8 Carbohydrates |
| 1.3 Protein folding | 1.9 Lipids |
| 1.4 Protein sequencing and assay | 1.10 Vitamins |
| 1.5 Nucleic acids | 1.11 Reactive oxygen species and antioxidants |
| 1.6 Structure of dsDNA | 1.12 Enzymes |

Biomolecules are *carbon-based organic compounds* that are produced by living organisms. Most biomolecules can be regarded as derivatives of hydrocarbons, with hydrogen atoms replaced by a variety of functional groups that confer specific chemical properties on the molecule. These molecules consist of a relatively small number of elements. Approximately 25 naturally occurring chemical elements are found in biomolecules, and most of these elements have a relatively low atomic number. In terms of the percentage of the total number of atoms, hydrogen, oxygen, nitrogen, and carbon together makeup over 99% of the mass of most cells. Biomolecules include both small as well as large molecules. The **small biomolecules** are low molecular weight (less than 1000) compounds which include sugars, fatty acids, amino acids, nucleotides, vitamins, hormones, neurotransmitters, primary and secondary metabolites. Sugars, fatty acids, amino acids, and nucleotides constitute the four major families of small biomolecules in cells. Each of these small biomolecules is composed of a small set of atoms linked to each other in a precise configuration through covalent bonds. **Large biomolecules** which have high molecular weight are called *macromolecules* and mostly are polymers of small biomolecules. These macromolecules are proteins, carbohydrates, and nucleic acids.

Small biomolecules

Sugars

Amino acids

Nucleotides

Macromolecules

Polysaccharides

Polypeptides (proteins)

Polynucleotides (nucleic acids)

Nucleic acids and proteins are **informational macromolecules**. Proteins are polymers of amino acids and constitute the largest fraction (besides water) of cells. The nucleic acids, DNA and RNA, are polymers of nucleotides. They store, transmit, and translate genetic information. The polysaccharides, polymers of monosaccharides, have two primary functions: serving as a storage form of energy and as extracellular structural components.

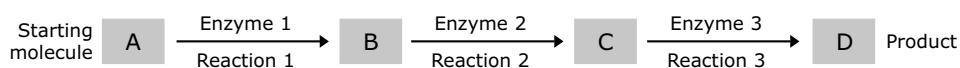


Metabolism

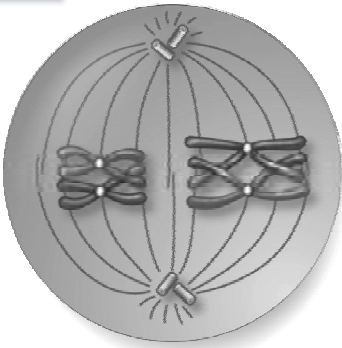
Learning objective

- | | | | |
|-----|---------------------------|------|-------------------------|
| 2.1 | Respiration | 2.6 | Photorespiration |
| 2.2 | Glyoxylate cycle | 2.7 | Carbohydrate metabolism |
| 2.3 | Pentose phosphate pathway | 2.8 | Lipid metabolism |
| 2.4 | Entner-Doudoroff pathway | 2.9 | Amino acid metabolism |
| 2.5 | Photosynthesis | 2.10 | Nucleotide metabolism |

All cells function as biochemical factories. Within the living cell, biomolecules are constantly being synthesized and transformed into some other biomolecules. This synthesis and transformation constantly occur through enzyme-catalyzed chemical reactions. More than a thousand chemical reactions take place in a cell. Most of these chemical reactions do not occur in isolation but are always linked to some other reactions. All the interconnected chemical reactions occurring within a cell are called **metabolism** (derived from the Greek word for a *change*). Metabolism serves two fundamentally different purposes: 1. Generation of energy to drive vital functions and 2. Synthesis of biological molecules. The precursor is converted into a product during metabolic processes through a series of metabolic intermediates called **metabolites**. Cell metabolism is organized by enzymes. Enzyme-catalyzed reactions are connected in series so that the product of one reaction becomes the starting material, or substrate, for the next. The series of enzyme-catalyzed reactions transform substrates into end products through many specific chemical intermediates constitutes a **metabolic pathway**. Metabolism is sometimes referred to as **intermediary metabolism**. The term *intermediary metabolism* is often applied to the enzyme-catalyzed reactions that extract chemical energy from nutrient molecules and use it to synthesize and assemble cell components. The flow of metabolites through the metabolic pathway has a definite rate and direction. Metabolism is highly organized and regulated. Metabolic pathways are regulated through control of (1) the amounts of enzymes, (2) their catalytic activities, and (3) the availability of substrates. In multicellular organisms, the metabolic activities of different tissues are also regulated and integrated by growth factors and hormones that act from outside the cell.



Metabolism consists of energy-yielding and energy-requiring reactions. The oxidation of carbon compounds is an important source of cellular energy. An energy currency common to all life forms, ATP, links energy-releasing pathways with energy-requiring pathways. ATP serves as the principal immediate donor of free energy in biological systems rather than as a long-term storage form of free energy.

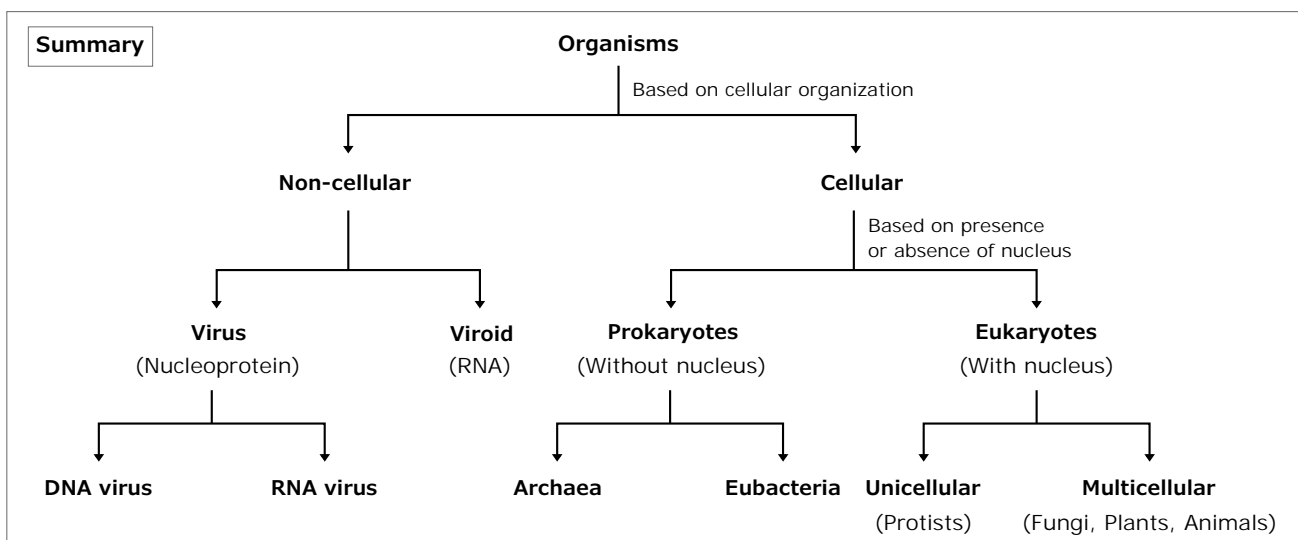


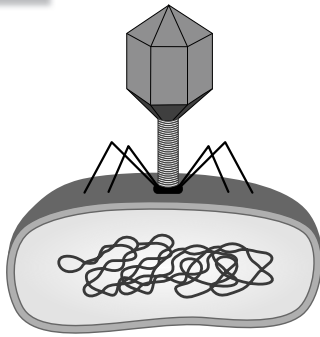
Cell Structure and functions

Learning objective

3.1 What is a cell?	3.9 Lysosome	3.17 Cell adhesion molecules
3.2 Plasma membrane	3.10 Vacuoles	3.18 Extracellular matrix of animals
3.3 Membrane potential	3.11 Mitochondria	3.19 Plant cell wall
3.4 Transport of macromolecules	3.12 Plastids	3.20 Cell signaling
3.5 Ribosomes	3.13 Peroxisome	3.21 Cell cycle
3.6 Endoplasmic reticulum	3.14 Nucleus	3.22 Mechanics of cell division
3.7 Golgi complex	3.15 Cytoskeleton	3.23 Apoptosis
3.8 Membrane fusion	3.16 Cell junctions	3.24 Cancer

A great diversity of organisms are present on the Earth. These organisms can be classified into two broad categories- **cellular organisms** and **non-cellular organisms**. Cellular organisms are further subdivided into three distinct domains of life: *bacteria*, *archaea*, and *eukarya*. Bacteria and archaea are classified as **prokaryotes**, characterized by the absence of a nucleus. All **eukaryotes** belong to domain *eukarya* which includes *protists*, *fungi*, *plants* and *animals*. Both prokaryotes and eukaryotes are *cellular organisms*. Viruses and viroids are non-cellular organisms because they lack cell or cell-like structure.





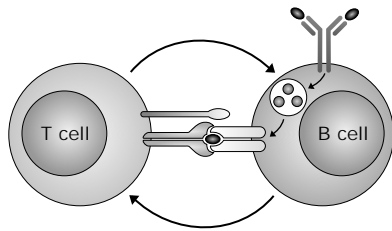
Prokaryotes and Viruses

Learning objective

- | | |
|------------------------------------------------|----------------------------------------------------|
| 4.1 Phylogenetic overview | 4.8 General features of important bacterial groups |
| 4.2 Structure of bacterial cell | 4.9 Archaeobacteria |
| 4.3 Bacterial genome | 4.10 Bacterial toxins |
| 4.4 Bacterial nutrition | 4.11 Control of microbial growth |
| 4.5 Horizontal gene transfer and recombination | 4.12 Viruses |
| 4.6 Mapping of chromosomal genes | 4.13 Prions and Viroids |
| 4.7 Bacterial taxonomy | |

Prokaryotes (*pro* means before and *karyon* means kernel or nucleus) are cellular organisms that include two domains— **Bacteria** (sometimes referred to as *true bacteria* or *eubacteria*) and **archaea** (also termed as *archaeobacteria* or *archaeobacteria*). The term *bacteria* or *eubacteria* refers to those that belong to the domain Bacteria, and the term *archaea* is used to refer to those that belong to domain Archaea. *The informal name 'bacteria' is occasionally used loosely in the literature to refer to all the prokaryotes, and care should be taken to interpret its meaning in any particular context.* Prokaryotic organisms are usually microscopic, single-celled organisms that have a relatively simple structure—neither nucleus nor unit membrane-bound organelles. Prokaryotes can be distinguished from eukaryotes in terms of their cell structure and molecular make-up. Prokaryotic cells have a simpler internal structure than eukaryotic cells. Although many structures are common to both cell types, some are unique to prokaryotes. Most prokaryotic cells lack extensive, complex internal membrane systems. The major distinguishing characteristics of prokaryotic and eukaryotic cells are as follows:

Feature	Prokaryotic cells	Eukaryotic cells
Membrane-bound nucleus	Absent	Present
DNA complexed with histone	Absent	Present
Number of chromosomes	One (mostly)	More than one
Mitosis and meiosis	Absent	Present
Sterol (in plasma membrane)	Absent, except <i>Mycoplasma</i>	Present
Ribosome	70S (cytosol)	80S (cytosol)
Unit-mem. bound organelle	Absent	Present
Cell wall	Present in <i>most</i> of prokaryotic cells. In eubacteria, it is made up of peptidoglycan.	Made up of cellulose in plant and chitin in fungi. Absent in animal cells.



Immunology

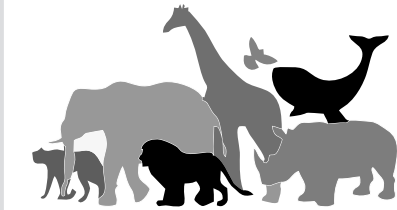
Learning objective

- | | |
|-----------------------------------------------------|-----------------------------------------------------|
| 5.1 Innate immunity | 5.11 Kinetics of the antibody response |
| 5.2 Adaptive immunity | 5.12 Monoclonal antibodies and Hybridoma technology |
| 5.3 Cells of the immune system | 5.13 T cells and cell-mediated immunity |
| 5.4 Organs involved in the adaptive immune response | 5.14 The complement system |
| 5.5 Antigens | 5.15 Hypersensitivity |
| 5.6 Major histocompatibility complex | 5.16 Autoimmunity |
| 5.7 Immunoglobulins: Structure and function | 5.17 Transplantation |
| 5.8 Organization and expression of Ig genes | 5.18 Immunodeficiency diseases |
| 5.9 Generation of antibody diversity | 5.19 Failures of host defense mechanisms |
| 5.10 B cell maturation and activation | 5.20 Vaccines |

Immunology is the science that is concerned with immune response to foreign challenges or simply, study of the body's defense against infection. It addresses the questions such as how does the body defend itself against infection, when an infection does occur, how does the body eliminate the pathogens and how does long-lasting immunity to many infectious diseases develop? The ability of an organism to resist infections by pathogens or state of protection against foreign organisms or substances is called **immunity** (derived from Latin term *immunis*, meaning 'exempt'). The array of cells, tissues and organs which carry out this activity constitute the **immune system**. The immune response is a complex process and is divided into two categories — **innate** (or **native**) and **adaptive** (or **acquired**) immunity. *Innate immunity* is a general, non-specific immune response which presents in all individuals at all times. In contrast to innate immunity, *adaptive immunity* is highly specific to the particular pathogen that induced it. It develops during the lifetime of an individual as a response to infection and adaptation to the infection. Thus, when a given pathogen is new to the host, it is initially recognized by the innate immune system and then the adaptive immune response is activated. Innate immunity is the most ancient form of defense, found in most multicellular organisms, while adaptive immunity is a recent evolutionary phenomenon, having arisen in vertebrates. Thus, vertebrates are protected by both innate immunity and adaptive immunity.

5.1 Innate immunity

Innate immunity is present since birth, evolutionarily primitive and is relatively nonspecific. It provides the *early defense* against pathogens, before adaptive immune responses can develop. It is not specific to any one pathogen but rather acts against all foreign molecules and pathogens. It also does not rely on previous exposure to a pathogen and response is functional since birth and has no memory.



Diversity of Life

Learning objective

6.1 Taxonomy

6.2 Five-kingdom system

6.3 Protists

6.4 Fungi

6.5 Plantae

6.6 Animalia

6.7 Animal's classification

Diversity of life can be summarized as 'variety of life on Earth.' The living world is enormously diverse. The total number of species on the Earth described so far is about 1.2 million. There are many more species that have not yet been described. Scientists are still discovering new species. Thus, we do not know for sure how many species really exist today. Current estimates of the total number of species range from 8 million to 10 million. The known species are unevenly distributed across taxonomic groups. More than 70 percent of all the species recorded are animals, while plants (including algae and fungi) comprise no more than 22 percent of the total. The variety of life on Earth plays a critical role in regulating the Earth's physical, chemical, and geological properties, from influencing the chemical and physical composition of the environment. To understand the diversity of life, it is important to organize the different kinds of organisms. Here the role of taxonomy comes which classify organisms in a way so that we can understand them better.

6.1 Taxonomy

In order to study the diversity of organisms, biologists have evolved certain rules and principles for identifying, describing, naming, and classifying organisms. The branch of science dealing with these aspects is referred to as **taxonomy** (*arrangement by the rules*). Taxonomy is often used as a synonym for **systematics**. Taxonomy can be considered as a branch of systematics. The main difference between taxonomy and systematics is that *taxonomy* is involved in the description, identification, nomenclature, and classification of organisms. In contrast, *systematics* is, in principle, broader, covering all aspects of relationships among organisms.

Levels of taxonomy: The discipline of taxonomy traditionally covers three areas: alpha, beta and gamma taxonomy.

Alpha taxonomy is concerned with finding, describing, and naming species. **Beta taxonomy** includes the identification of natural groups and biological classes. **Gamma taxonomy** includes the study of evolutionary processes and patterns.

Organisms were first classified more than 2,000 years ago by Greek philosopher *Aristotle*. He classified organisms as either plant or animal. Modern biological classification began with the eighteenth-century Swedish naturalist *C. Linnaeus*. He established a simple system for classifying and naming organisms. He developed a hierarchy (a ranking system) for classifying organisms that is the basis for modern taxonomy.



Ecology

Learning objective

- | | |
|---------------------------------|--------------------------------------------------|
| 7.1 The Environment | 7.9 Island biogeography |
| 7.2 Shelford's law of tolerance | 7.10 Ecological interdependence and interactions |
| 7.3 Ecosystem | 7.11 Lotka-Volterra model |
| 7.4 Ecosystem services | 7.12 Ecological niche |
| 7.5 Types of Ecosystems | 7.13 Effect of competition |
| 7.6 Biomes | 7.14 Ecological succession |
| 7.7 Population ecology | 7.15 Biodiversity |
| 7.8 Community ecology | 7.16 Behavioural ecology |

Ecology is the scientific study of the relationships between organisms and their environment. These relationships are complex, varied and hierarchical. The word 'ecology' was first used by German biologist Ernst Haeckel in 1869. It is derived from the Greek words, *oikos* (meaning 'house' or 'dwelling place') and *logos* (meaning the study of). Haeckel defined ecology as '*the study of the natural environment including the relations of organisms to one another and to their surroundings*'. Ecology describes the relationships between living organisms and their environments, the interaction of organisms with each other and the pattern and cause of the abundance and distribution of organisms in nature. It is the science that attempts to answer questions about how the nature works.

7.1 The Environment

Organisms and their environments are dynamic and interdependent. The term '**environment**' etymologically means *surroundings*. It includes everything (biotic as well as abiotic) that surrounds an organism. Any factor, abiotic or biotic, that influences living organisms is called **environmental factor** (or *ecological factor* or *ecofactor*). **Abiotic factors** include factors such as temperature, sunlight levels, pH, salinity and soil composition. In contrast, **biotic factors** encompass producers, consumers and decomposers.

7.1.1 Physical environment

Soil

Soil constitutes the uppermost weathered layer of the Earth's crust. It is a mixture of weathered mineral rock particles, organic matter (i.e. both living and dead), water and air. Soil is a biologically active matrix and home of diverse organisms. The scientific discipline dedicated to the study of soil is known as **pedology**.

A letter from Bruce Alberts

(author of Molecular Biology of the Cell)



To: "Usha Mina" <ushamina@mail.jnu.ac.in>
Sent: Tuesday, January 3, 2023 11:14:02 AM
Subject: Re: Review of book

Some feedback on your two Life Sciences volumes – for authors only Bruce Alberts

Dear Usha and Pranav,

I have finally finished reading through many sections of your large two-volume introductory biology textbook, and I write to provide some feedback that might possibly help with your next edition.

Let me start by saying how impressed I am that such a wide-ranging textbook was written by only two authors. For those sections where I am most knowledgeable – which I read closely -- I find it to be remarkably accurate. As you well know, most such textbooks that attempt to cover all of biology are written by a sizeable team of authors – each with a different expertise -- who in addition acknowledge help from a large number of other experts. And it is great to learn that you are able to provide these two volumes at a low price that Indian students can afford.

My first question concerns the way that this material has been divided up into two separate volumes. If I were a student, I would have felt a need to learn about genetic mechanisms (which you call “genetics”) in volume 1, before learning about how proteins are sorted through internal membranes, for example.

A major concern that I would have is one of level. I find that in many places you go into considerably more detail than we do in MBOC (molecular biology of the cell), even though the latter book is aimed at a more advanced student population than I believe yours is. Biology is such a huge subject that we can easily lose students in all the details, when what is most important for them to learn are the concepts. Students often feel a need to memorize such details: in our interviews with sets of students who had just used our textbook, we found that many (most?) lack the judgement to ignore them when preparing for exams. For the same reason, we also leave out many of the scientific words in our book, like 2.2₇ helix, linking number, abzyme, etc.

I hope that you find these comments useful, and I write to wish you the very best in 2023, as well as to encourage you in all of your future efforts!

With my best wishes,

Bruce

Pathfinder Publication



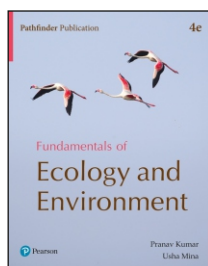
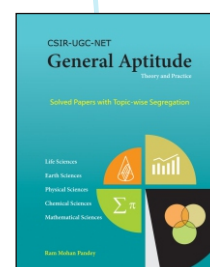
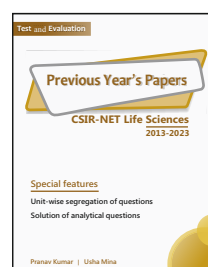
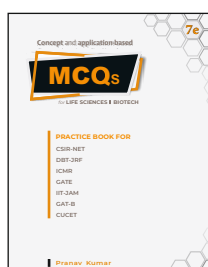
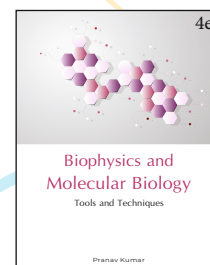
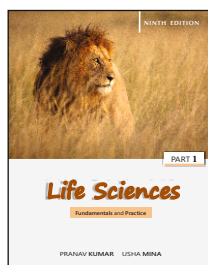
Pathfinder's **CSIR NET** **Life Sciences**

Complete Study Material

by **Pranav Kumar**



9818063394



amazon

#1 Best Seller

Click here to buy now

<https://pathfinderacademy.in/book/csir-net-life-sciences-combo-with-ecology-11.html>

Connect with Us



TELEGRAM DISCUSSION GROUP

https://t.me/CSIR_NET_Life_Sciences_GATE_BT



<https://www.youtube.com/@Pathfinder-Academy>



<https://www.instagram.com/pathfinderacademy/>



<https://www.facebook.com/PathfinderAcademy.in>

NINTH EDITION



PART 2

Life Sciences

Fundamentals and Practice

PRANAV KUMAR USHA MINA

Life Sciences

Fundamentals and Practice

Part-2

Ninth edition

PRANAV KUMAR

Former faculty,
Department of Biotechnology,
Jamia Millia Islamia (JMI),
New Delhi, India

USHA MINA

Professor,
School of Environmental Sciences,
Jawaharlal Nehru University (JNU),
New Delhi, India



Pathfinder Publication

New Delhi, India



Pranav Kumar

Former faculty,
Department of Biotechnology,
Jamia Millia Islamia (JMI),
New Delhi, India



Usha Mina

Professor,
School of Environmental Sciences,
Jawaharlal Nehru University (JNU),
New Delhi, India

Life Sciences: Fundamentals and Practice

Ninth edition

ISBN: 978-81-956333-8-8 (paperback)

Copyright © 2024 by Pathfinder Publication, all rights reserved.

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

No part of this book may be reproduced by any mechanical, photographic, or electronic process, or in the form of a phonographic recording, nor it may be stored in a retrieval system, transmitted, or otherwise copied for public or private use, without written permission from the publisher.

Publisher : Pathfinder Publication

Illustration and layout : Pradeep Verma

Cover design : Pradeep Verma

Marketing director : Arun Kumar

Production coordinator : Murari Kumar Singh

Pathfinder Publication

A unit of Pathfinder Academy Private Limited, New Delhi, India.

pathfinderpublication.in

Contents

Chapter 1

Genetics

1.1	Mendel's principles	1	1.10	Cytogenetics	68
1.1.1	Mendel's laws of inheritance	4	1.10.1	Human karyotype	68
1.1.2	Incomplete dominance and codominance	8	1.10.2	Chromosome banding	69
1.1.3	Multiple alleles	10	1.10.3	Chromosomal abnormalities	71
1.1.4	Lethal alleles	11		Variation in chromosome number	71
1.1.5	Penetrance and expressivity	12		Variation in chromosome structure	74
1.1.6	Probability	12	1.10.4	Position effect variegation	79
1.2	Chromosomal basis of inheritance	15	1.11	Genome	80
1.3	Gene interaction	17	1.11.1	Genome complexity	82
1.3.1	Genetic dissection	23	1.11.2	Gene	84
1.3.2	Complementation analysis	24	1.11.3	Introns	85
1.3.3	Pleiotropy	27	1.11.4	Gene duplication	88
1.4	Linkage and gene mapping	27	1.11.5	Acquisition of new genes	89
1.4.1	Genetic mapping	33	1.11.6	Gene families	90
1.4.2	Gene mapping from two point cross	34	1.11.7	Human nuclear genome	92
1.4.3	Gene mapping from three point cross	36	1.11.8	Yeast <i>S. cerevisiae</i> genome	93
1.4.4	Interference and coincidence	38	1.11.9	<i>E. coli</i> genome	93
1.5	Tetrad analysis	40	1.11.10	Organelle genome	93
1.5.1	Analysis of ordered tetrad	41	1.11.11	Transposable elements	95
1.5.2	Analysis of unordered tetrad	43	1.12	Eukaryotic chromatin	103
1.6	Sex determination	44	1.12.1	Packaging of DNA into chromosomes	105
1.6.1	Sex-linked traits/sex-linked inheritance	50	1.12.2	Heterochromatin and euchromatin	110
1.6.2	Sex-limited traits	52	1.12.3	Polytene chromosomes	113
1.6.3	Sex-influenced traits	52	1.12.4	Lampbrush chromosomes	114
1.7	Pedigree analysis	53	1.12.5	B-chromosomes	115
1.8	Quantitative inheritance	57	1.13	DNA replication	116
1.8.1	Quantitative trait locus analysis	61	1.13.1	Semiconservative replication	116
1.8.2	Heritability	61	1.13.2	Replicon and origin of replication	117
1.9	Extranuclear inheritance and maternal effect	62	1.13.3	DNA replication in <i>E. coli</i>	121
1.9.1	Maternal effect	67	1.13.4	Telomere replication	135
			1.13.5	Rolling circle replication	136

1.13.6	Replication of mitochondrial DNA	137
1.14	Recombination	138
1.14.1	Homologous recombination	138
1.14.2	Site-specific recombination	143
1.15	DNA repair	145
1.15.1	Direct repair	145
1.15.2	Excision repair	146
1.15.3	Mismatch repair	147
1.15.4	Recombinational repair	148
1.15.5	Repair of double strand DNA break	150
1.15.6	Gene conversion	151
1.15.7	SOS response	152
1.16	Transcription	153
1.16.1	Transcription unit	153
1.16.2	Prokaryotic transcription	156
1.16.3	Eukaryotic transcription	162
1.16.4	Role of activator and co-activator	167
1.16.5	Regulatory elements	168
1.16.6	DNA binding motifs	170
1.17	RNA processing	173
1.17.1	Processing of eukaryotic pre-mRNA	173
1.17.2	Processing of pre-rRNA	184
1.17.3	Processing of pre-tRNA	187
1.18	mRNA degradation	188
1.19	Regulation of bacterial genes	190
1.19.1	Operon model	191
1.19.2	Tryptophan operon in <i>E. coli</i>	199
1.19.3	Riboswitches	204
1.20	Genetic switch in phage lambda	205
1.21	Regulation of eukaryotic genes	209
1.21.1	Chromatin structure on transcription	210
1.21.2	DNA methylation and gene regulation	214
1.21.3	Post-transcriptional gene regulation	216
1.22	RNA interference	217
1.23	Epigenetics	221
1.24	Genetic code	222
1.25	Protein synthesis	227
1.25.1	Translational frameshifting	244
1.25.2	Antibiotics and toxins	245

1.25.3	Post-translational modification of polypeptides	247
--------	-------------------------------------------------	-----

1.26	Mutation	249
1.26.1	Mutagens	254
1.26.2	Types of mutation	258
1.26.3	Fluctuation test	263
1.26.4	Ames test	264

Chapter 2

Recombinant DNA Technology

2.1	DNA cloning	271
2.2	Enzymes for DNA manipulation	273
2.2.1	DNA polymerase	273
2.2.2	Nucleases	273
2.2.3	End-modification enzymes	277
2.2.4	Ligases	278
2.3	Vectors	279
2.3.1	Vectors for <i>E. coli</i>	280
2.3.2	Cloning vectors for yeast, <i>S. cerevisiae</i>	284
2.3.3	Vectors for plants	286
2.3.4	Vectors for animals	290
2.4	Introduction of DNA into the host cells	290
2.4.1	In bacterial cells	290
2.4.2	In plant cells	290
2.4.3	In animal cells	293
2.5	Selectable and screenable marker	295
2.6	Selection of transformed bacterial cells	297
2.7	Selection of recombinant containing transformed bacterial cells	298
2.8	Expression vector	299
2.8.1	Expression system	300
2.8.2	Fusion protein	301
2.9	DNA library	302
2.10	Genetic markers	305
2.11	Genome mapping	312
2.11.1	Radiation hybrids	314
2.12	DNA profiling	315
2.13	Genetic manipulation of animal cells	316

2.13.1	Transgenesis and transgenic animals	316	3.3	Absorption and radial movement of mineral nutrients	366
2.13.2	Gene knockout	317	3.4	Mineral nutrition	367
2.13.3	Formation and selection of recombinant ES cells	319	3.4.1	Nitrogen assimilation	371
2.14	Nuclear transfer technology and animal cloning	320	3.4.2	Biological nitrogen fixation	374
2.15	Gene therapy	321	3.5	Translocation in the phloem	378
2.16	Transgenic plants	325	3.5.1	Allocation and partitioning of photoassimilates	387
2.16.1	Procedure to make a transgenic plant	325	3.6	Plant hormones	387
2.16.2	Antisense technology	329	3.6.1	Auxin	388
2.16.3	Molecular farming	330	3.6.2	Gibberellins	393
2.17	Plant tissue culture	330	3.6.3	Cytokinins	396
2.17.1	Cellular totipotency	331	3.6.4	Abscisic acid	400
2.17.2	Tissue culture media	331	3.6.5	Ethylene	401
2.17.3	Types of cultures	333	3.6.6	Brassinosteroids	403
2.17.4	Somaclonal and gametoclonal variation	338	3.6.7	Strigolactones	403
2.17.5	Somatic hybridization and cybridization	338	3.6.8	Jasmonates	404
2.17.6	Applications of cell and tissue culture	339	3.7	Signaling photoreceptors	404
2.18	Animal cell culture	342	3.7.1	Phytochrome	404
2.18.1	Primary cultures	342	3.7.2	Cryptochrome	408
2.18.2	Cell line	342	3.7.3	Phototropin	411
2.18.3	Growth cycle	344	3.7.4	Photoperiodism	413
2.18.4	Culture media	345	3.7.5	Florigen	415
			3.8	Vernalization	416
			3.9	Flowering genes	416
			3.10	Plants movements	419
			3.11	Seed dormancy and Germination	422
			3.12	Plant development	425
			3.12.1	Pollination and Self-incompatibility	431
			3.13	Asexual reproduction	432
			3.14	Embryogenesis	434
			3.14.1	Apical meristems	437
				Root apical meristems	437
				Shoot apical meristem	438
			3.15	Plant secondary metabolites	441
			3.15.1	Terpenes	441
			3.15.2	Phenolics	443
			3.15.3	Glycosides	445
			3.15.4	Alkaloids	445

Chapter 3

Plant Physiology and Development

3.1	Plant-water relationship	352
3.1.1	Diffusion and osmosis	352
3.1.2	Chemical potential of water	354
3.1.3	Mass flow	356
3.2	Journey of water in plant	356
3.2.1	Absorption of water	356
3.2.2	Radial movement of water from root surface to the tracheary element	358
3.2.3	Ascent of sap	359
3.2.4	Transpiration	362
3.2.5	Guttation	365

Chapter 4

Human Physiology

- 4.1 Tissues 451
 - 4.1.1 Organ systems of the human body 460
- 4.2 Nervous Systems 461
 - 4.2.1 Histology of nervous tissue 462
 - Neurons 462
 - Neuroglia 464
 - 4.2.2 Structural organization of CNS 465
 - Blood-brain barrier 466
 - 4.2.3 Major parts of the brain 467
 - Limbic system 469
 - 4.2.4 Spinal cord 470
 - Reflex and reflex arc 473
 - 4.2.5 Peripheral nervous system 473
 - 4.2.6 Autonomic nervous system 475
 - Somatic system 478
- 4.3 Sensory organs 479
 - 4.3.1 Eye 479
 - 4.3.2 Ear 485
- 4.4 Endocrine System 488
 - 4.4.1 Hypothalamus 489
 - 4.4.2 Pituitary gland 491
 - 4.4.3 Pineal gland 493
 - 4.4.4 Thyroid gland 493
 - 4.4.5 Parathyroid gland 494
 - 4.4.6 Thymus gland 494
 - 4.4.7 Pancreas 494
 - 4.4.8 Adrenal glands 497
 - 4.4.9 Gonadal hormone 499
 - 4.4.10 Hormones from kidney, heart, placenta and gastrointestinal tract 499
 - 4.4.11 General mechanisms of hormone action 501
 - 4.4.12 Hormones and diseases 502
- 4.5 Respiratory System 505
 - 4.5.1 Respiratory organs 505
 - 4.5.2 Mechanics and breathing 509
 - 4.5.3 Respiratory volumes and capacities 511
 - 4.5.4 Exchange of oxygen and carbon dioxide 512
 - 4.5.5 Transport of oxygen and carbon dioxide 515
 - 4.5.6 Control of respiration 518
 - 4.5.7 Chemoreceptor 519
 - 4.5.8 Disorders of respiratory system 520
- 4.6 Cardiovascular System 521
 - 4.6.1 Blood 521
 - 4.6.2 Heart 527
 - 4.6.3 Blood vessels 534
 - 4.6.4 Circulatory routes 538
 - 4.6.5 Lymphatic system 541
 - 4.6.6 Intracellular and extracellular fluid 542
 - 4.6.7 Cardiovascular disorders 542
- 4.7 Digestive System 543
 - 4.7.1 Gastrointestinal tract 543
 - 4.7.2 Accessory digestive organs 552
 - 4.7.3 Digestion of foods 555
 - 4.7.4 Absorption of foods 558
 - 4.7.5 Regulation of digestive function 560
- 4.8 Excretory System 561
 - 4.8.1 Structure of the kidneys 562
 - 4.8.2 Nephron 564
 - 4.8.3 Urine formation 567
 - 4.8.4 Atrial Natriuretic peptide 574
 - 4.8.5 Countercurrent exchange 577
- 4.9 Reproductive System 578
 - 4.9.1 Male reproductive system 578
 - Testis 578
 - Accessory ducts 578
 - Accessory glands 579
 - Spermatogenesis 579
 - 4.9.2 Female reproductive system 581
 - Ovaries 581
 - Accessory ducts 582
 - External genitalia 582
 - Oogenesis 583
 - Folliculogenesis 584
 - Hormones control 585
 - 4.9.3 Female reproductive cycle 585
 - Ovarian cycle 585
 - Uterine cycle 585

Chapter 5

Animal Development

- 5.1 Patterns and processes of animal development 593
 - 5.1.1 Cell-to-Cell communication 594
 - Wnt signaling 594
 - Hedgehog signaling 595
 - Notch signaling 597
 - 5.1.2 Cell fate commitment 599
 - 5.1.3 Morphogens 603
 - 5.1.4 Pattern formation and morphogenesis 604
- 5.2 Fertilization 607
- 5.3 Cleavage and gastrulation 615
 - Gastrulation 616
 - Early development in sea urchins – cleavage, gastrulation and axis formation 617
 - Gastrulation in the sea urchin 619
 - Early development in amphibia – cleavage, gastrulation and axis formation 621
 - Gastrulation in amphibia 622
 - Organogenesis 629
- 5.4 Embryonic development in *Drosophila* 629
- 5.5 Vulva development in *C. elegans* 639
- 5.6 Regeneration 641
- 6.5 Population genetics 663
 - 6.5.1 Calculation of allelic frequencies 664
 - 6.5.2 Hardy-Weinberg principle 665
 - 6.5.3 Inbreeding 670
 - Wahlund effect 674
 - Effective population size 675
- 6.6 Evolutionary processes 676
 - Natural selection 676
 - Genetic drift 677
 - Mutation 680
- 6.7 Species and speciation 682
 - Concept of species 682
 - Reproductive isolation 683
 - Speciation 684
 - Anagenesis and cladogenesis 686
 - Adaptive radiation 687
- 6.8 Macroevolution 687
- 6.9 Molecular phylogeny 689
 - Molecular clock 690
- 6.10 Phylogenetic tree 691
- 6.11 Geological time scale 693

Index 699

Chapter 6

Evolution

- 6.1 Origin of Life 649
- 6.2 Biological evolution and theories of evolution 652
 - 6.2.1 Lamarckism 652
 - 6.2.2 Darwinism 653
- 6.3 Natural selection 657
 - Evidences of natural selection 658
 - Level of natural selection 659
 - How selection works 659
 - Modes of natural selection 660
 - Sexual selection 661
- 6.4 Pattern of evolution 662



Genetics

Learning objective

1.1 Mendel's principles	1.10 Cytogenetics	1.19 Regulation of bacterial genes
1.2 Chromosomal basis of inheritance	1.11 Genome	1.20 Genetic switch in phage lambda
1.3 Gene interaction	1.12 Eukaryotic chromatin	1.21 Regulation of eukaryotic genes
1.4 Linkage and gene mapping	1.13 DNA replication	1.22 RNA interference
1.5 Tetrad analysis	1.14 Recombination	1.23 Epigenetics
1.6 Sex determination	1.15 DNA repair	1.24 Genetic code
1.7 Pedigree analysis	1.16 Transcription	1.25 Protein synthesis
1.8 Quantitative inheritance	1.17 RNA processing	1.26 Mutation
1.9 Extranuclear inheritance	1.18 mRNA degradation	

All living organisms reproduce. Reproduction results in the formation of offspring of the same kind. However, the resulting offsprings need not and, most often, do not completely resemble the parents. Several characteristics may differ between individuals belonging to the same species. These differences are termed **variations**. The mechanism of transmission of characters, resemblances, and differences from the parental generation to the offspring is called **heredity**. The scientific study of heredity and variations is known as **genetics** (from the Greek word *genno* = give birth). The word 'genetics' was first suggested by prominent British scientist William Bateson. Genetics can be divided into three areas: *classical genetics*, *molecular genetics*, and *evolutionary genetics*. **Classical genetics** is concerned with the basic principles of heredity and how traits are passed from one generation to the next. It also addresses the relationship between chromosomes and heredity and the arrangement of genes on chromosomes. **Molecular genetics** covers the chemical nature of the gene and how genetic information is replicated and expressed, i.e., cellular processes of replication, transcription, and translation. **Evolutionary genetics** is the study of how genetic variation leads to evolutionary change. It is concerned with the evolution of genome structure, the genetic basis of speciation and adaptation, and genetic change in response to evolutionary processes such as natural selection, genetic drift, mutation, and gene flow in populations.

Classical genetics

1.1 Mendel's principles

Gregor Johann Mendel (1822–1884), known as the *father of genetics*, was an Austrian monk. He conducted a series of experiments using pea plants and showed that traits are passed from parents to offspring in predictable ways. By quantitative data analysis of results, he concluded that each trait in the pea plant is controlled by a pair of factors



Recombinant DNA technology

Learning objective

- | | |
|---------------------------------------------------------|-----------------------------------------------------|
| 2.1 DNA cloning | 2.10 Genetic markers |
| 2.2 Enzymes for DNA manipulation | 2.11 Genome mapping |
| 2.3 Vectors | 2.12 DNA profiling |
| 2.4 Introduction of DNA into the host cells | 2.13 Genetic manipulation of animal cells |
| 2.5 Selectable and screenable marker | 2.14 Nuclear transfer technology and animal cloning |
| 2.6 Selection of transformed bacterial cells | 2.15 Gene therapy |
| 2.7 Selection of recombinant containing bacterial cells | 2.16 Transgenic plants |
| 2.8 Expression vector | 2.17 Plant tissue culture |
| 2.9 DNA library | 2.18 Animal cell culture |

Recombinant DNA technology (also known as **genetic engineering**) is the set of techniques that enable the DNA from different sources to be identified, isolated and recombined so that new characteristics can be introduced into an organism. The invention of recombinant DNA technology—the way in which genetic material from one organism is artificially integrated into the genome of another organism and then replicated and expressed by that other organism—was largely the work of Paul Berg, Herbert W. Boyer and Stanley N. Cohen, although many other scientists also made important contributions to the new technology as well. Paul Berg developed the first recombinant DNA molecules that combined DNA from the SV40 virus and lambda phage. Later in 1973, Herbert Boyer and Stanley Cohen develop recombinant DNA technology, showing that genetically engineered DNA molecules may be developed and cloned in foreign cells. One important aspect of recombinant DNA technology is **DNA cloning**. It is a set of techniques that are used to design recombinant DNA molecules and to direct their replication within host organisms. The use of the word 'cloning' refers to the method used to generate identical DNA molecules.

2.1 DNA cloning

DNA cloning is the production of a large number of identical DNA molecules from a single ancestral DNA molecule. The essential characteristic of DNA cloning is that the desired DNA fragments must be *selectively amplified*, resulting in a large increase in copy number of selected DNA sequences. In practice, this involves multiple rounds of DNA replication catalyzed by a DNA polymerase acting on one or more types of the template DNA molecule. Essentially two different DNA cloning approaches are used: *Cell-based* and *cell-free DNA cloning*.



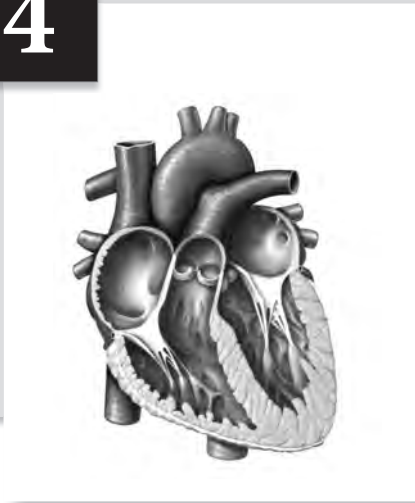
Plant Physiology and Development

Learning objective

- | | |
|---------------------------------------------------------|------------------------------------|
| 3.1 Plant-water relationship | 3.9 Flowering genes |
| 3.2 Journey of water in plant | 3.10 Plants movements |
| 3.3 Absorption and radial movement of mineral nutrients | 3.11 Seed dormancy and Germination |
| 3.4 Mineral nutrition | 3.12 Plant development |
| 3.5 Translocation in the phloem | 3.13 Asexual reproduction |
| 3.6 Plant hormones | 3.14 Embryogenesis |
| 3.7 Signaling photoreceptors | 3.15 Plant secondary metabolites |
| 3.8 Vernalization | |

Plants are multicellular, photoautotrophic eukaryotic organisms. It includes algae, bryophytes, pteridophytes, gymnosperms, and angiosperms. Bryophytes, pteridophytes, gymnosperms, and angiosperms are usually referred to as **land plants**. Angiosperms (also called **flowering plants**) are a major group of land plants. These plants are by far the most numerous, diverse, and successful terrestrial plants, representing more than 90% of all land plant species alive today. They range in size from tiny, almost microscopic *Wolfia* to tall trees of Eucalyptus (over 100 meters). Angiosperms are **vascular plants** containing two types of vascular tissue – **xylem** that conducts water and dissolved minerals upward from the roots and **phloem** that conducts food throughout the plant. Vascular tissues develop in the sporophytic body but (with a few exceptions) not in the gametophytic body. Angiosperms are also classified as **spermatophytes** (also known as **phanerogams**) because they produce seeds. A **seed** is an embryo packaged with a supply of nutrients inside a protective coat. In angiosperms, seeds develop inside ovaries, which mature into fruits. The seed is a crucial adaptation to life on land because it protects the embryo from drying out. A typical flowering plant body can be divided into the **root** and **shoot systems**. The underground part of the flowering plant is the *root system*, while the portion above the ground forms the *shoot system*. The shoot system consists of stems, leaves, flowers and fruits.

Root is typically a non-green underground structure. The first root in a vascular plant develops from the **radicle** of the embryo. The root develops from the direct elongation of the radicle is known as the **primary root**. Any root that develops from plant organs other than radicle is called an **adventitious root**. The primary root continues to grow and develops **lateral roots** (or **branch roots**) of several orders that are referred to as *secondary roots*, *tertiary roots* and so on. The primary roots and its branches constitute the **tap root system**. Commonly, the primary root in monocots such as wheat is short-lived, and it is replaced by the roots developing from the base of the stem. These stem-borne roots and their lateral roots constitute **fibrous root system**. The main functions of the root are absorption of water and minerals from the soil, anchorage, storage of reserve food material and synthesis of plant growth regulators. But, roots in some plants become modified to perform functions (such as respiration, support) other than anchorage and absorption of water and minerals.



Human Physiology

Learning objective

- 4.1 Tissues
- 4.2 Nervous Systems
- 4.3 Sensory organs
- 4.4 Endocrine System
- 4.5 Respiratory System

- 4.6 Cardiovascular System
 - 4.7 Digestive System
 - 4.8 Excretory System
 - 4.9 Reproductive System
-

Like all multicellular animals, human body is composed of different types of cells. Groups of cells similar in structure and function are organized into *tissues*. Different tissues grouped together into a structural and functional unit called *organs*. An *organ system* is a group of organs that function together to carry out the principal activities of the body.

4.1 Tissues

A *tissue* is a group of similar cells that usually have a common embryonic origin and functions together to carry out specialized activities. On the basis of structure and function, animal tissues can be classified into four basic types: epithelial tissue, connective tissue, nervous tissue and muscular tissue.

1. Epithelial tissue

An *epithelial tissue* or **epithelium** consists of cells that form membranes, which cover and line the body surfaces and glands, which are derived from these membranes. Epithelial cells arranged in continuous sheets, in either single or multiple layers. Because the cells are closely packed and are held tightly together by many cell junctions, there is little intercellular space between cells. Three types of cell junctions are found in the epithelium and other tissues. These cell junctions are called as *tight*, *anchoring* (adherens junction and desmosome) and *gap junctions*. Epithelial tissue has its own nerve supply, but is **avascular**; that is, it lacks its own blood supply. The blood vessels that bring in nutrients and remove wastes are located in the adjacent connective tissue. Exchange of substances between epithelium and connective tissue occurs by diffusion. Epithelial tissue plays many roles such as protection, filtration, secretion, absorption and excretion. Because epithelial tissue subjected to wear and tear and injury, it has high capacity for renewal.



Animal Development

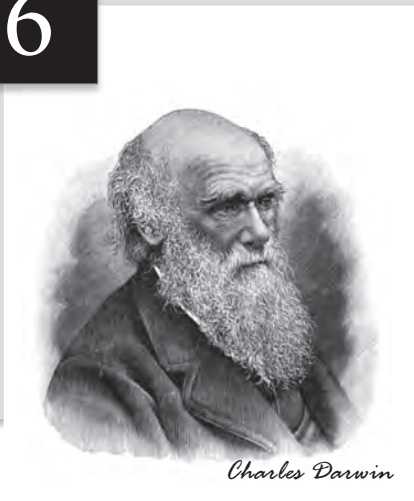
Learning objective

-
- | | | | |
|-----|----------------------------------------------|-----|--------------------------------------------|
| 5.1 | Patterns and processes of animal development | 5.4 | Embryonic development in <i>Drosophila</i> |
| 5.2 | Fertilization | 5.5 | Vulva development in <i>C. elegans</i> |
| 5.3 | Cleavage and gastrulation | 5.6 | Regeneration |
-

Animal development is a highly complex process that begins with a fertilized egg (or zygote) and leads to the birth of a complex organism with organs at precise positions and shapes. The stages of development between fertilization and birth are collectively called **embryogenesis** and its study is called **embryology**. Embryonic development begins with the fusion of the male and female gametes (**fertilization**). After fertilization, a multicellular organism's development proceeds through a process called **cleavage**, a series of mitotic divisions. Cleavage divides the zygote into numerous cells called *blastomeres*. By the end of cleavage, a solid or hollow fluid-filled ball of the blastomeres develops, known as a **blastula**. Cleavage is followed by **gastrulation**, a process that rearranges the blastomeres and forms the germ layers — *ectoderm*, *mesoderm*, and *endoderm*. Over time and space, these cells interact with one another and rearrange themselves to produce tissues and organs. This process is called **organogenesis**. Many animals have life cycles involving a larval stage specialized for feeding and dispersal. The larva undergoes **metamorphosis** to become a sexually mature adult.

5.1 Patterns and processes of animal development

Developmental biology aims to understand how an organism develops. During development, the zygote divides repeatedly to produce many different kinds of cells arranged in a specific pattern i.e., cells are organized in space and time so that a well-ordered structure develops within the embryo. Several key processes fundamentally occur during animal development. These processes include *cell proliferation*, which produces many cells from one; *cell-cell communications*, which coordinate the behavior of each cell with that of its neighbors; *cell differentiation*, which creates cells with different characteristics at different positions; and *cell movement*, which rearranges the cells to form structured tissues and organs.



Evolution

Learning objective

- | | | | |
|-----|------------------------------------------------|------|------------------------|
| 6.1 | Origin of Life | 6.7 | Species and speciation |
| 6.2 | Biological evolution and theories of evolution | 6.8 | Macroevolution |
| 6.3 | Natural selection | 6.9 | Molecular phylogeny |
| 6.4 | Pattern of evolution | 6.10 | Phylogenetic tree |
| 6.5 | Population genetics | 6.11 | Geological time scale |
| 6.6 | Evolutionary processes | | |

Evolution refers to the changes that occur in life forms over time, leading to the development of many different forms of life. By understanding evolution, we can gain insight into how and why life has changed and diversified. It includes the study of evolutionary processes—how they operate, what they produce, and how they are likely to proceed in the future. It deals mainly with how life changed after its origin. It does not discuss about the *origin of life*. To understand evolution, it is also very important to understand how life originated? We should understand the physical and chemical conditions prevailing on the prebiotic Earth that could drive the first steps of the origin of life. We also have to address a simple question central to our understanding of the origin of life: how complex organic molecules formed and how they have become organized into cells?

6.1 Origin of Life

Life is characterized by the three functions: 1. **compartmentalization**: the ability to keep its components together and separate itself from the environment, 2. **replication**: the ability to process and transmit heritable information to progeny, and 3. **metabolism**: the ability to capture and utilize the energy and material resources, staying away from thermodynamic equilibrium.

The origin of life on Earth is a unique event and also one of the great mysteries. *Where and how did life on Earth originate?* It is difficult to determine because it began almost four billion years ago. Did life come from outer space? For a long time, it was believed that life didn't begin on Earth. It came from outside (i.e. extraterrestrial origin). However, due to lack of any validation, it remained merely speculative. For many years it was also believed that life came out of decaying and rotting organic matters. This theory was termed as **theory of spontaneous generation**. Scientists have disproved this theory by performing controlled experiments. Louis Pasteur by careful experimentation demonstrated that life comes only from pre-existing life. Living things, no matter how small, do not come spontaneously from non-living matters. Living things come only from other living things (**biogenesis**). However, this did not answer how the first life form came on Earth.

A letter from Bruce Alberts

(author of Molecular Biology of the Cell)



To: "Usha Mina" <ushamina@mail.jnu.ac.in>
Sent: Tuesday, January 3, 2023 11:14:02 AM
Subject: Re: Review of book

Some feedback on your two Life Sciences volumes – for authors only Bruce Alberts

Dear Usha and Pranav,

I have finally finished reading through many sections of your large two-volume introductory biology textbook, and I write to provide some feedback that might possibly help with your next edition.

Let me start by saying how impressed I am that such a wide-ranging textbook was written by only two authors. For those sections where I am most knowledgeable – which I read closely -- I find it to be remarkably accurate. As you well know, most such textbooks that attempt to cover all of biology are written by a sizeable team of authors – each with a different expertise -- who in addition acknowledge help from a large number of other experts. And it is great to learn that you are able to provide these two volumes at a low price that Indian students can afford.

My first question concerns the way that this material has been divided up into two separate volumes. If I were a student, I would have felt a need to learn about genetic mechanisms (which you call “genetics”) in volume 1, before learning about how proteins are sorted through internal membranes, for example.

A major concern that I would have is one of level. I find that in many places you go into considerably more detail than we do in MBOC (molecular biology of the cell), even though the latter book is aimed at a more advanced student population than I believe yours is. Biology is such a huge subject that we can easily lose students in all the details, when what is most important for them to learn are the concepts. Students often feel a need to memorize such details: in our interviews with sets of students who had just used our textbook, we found that many (most?) lack the judgement to ignore them when preparing for exams. For the same reason, we also leave out many of the scientific words in our book, like 2.2₇ helix, linking number, abzyme, etc.

I hope that you find these comments useful, and I write to wish you the very best in 2023, as well as to encourage you in all of your future efforts!

With my best wishes,

Bruce

Pathfinder Publication



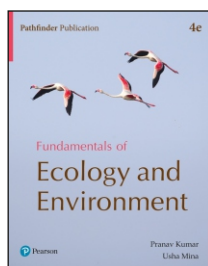
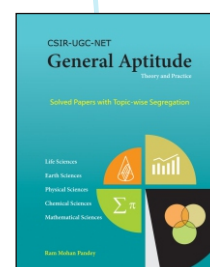
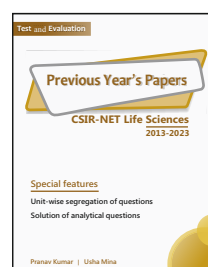
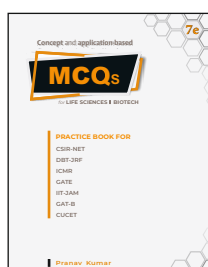
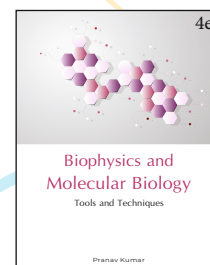
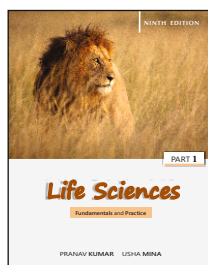
Pathfinder's **CSIR NET** **Life Sciences**

Complete Study Material

by **Pranav Kumar**



9818063394



amazon

#1 Best Seller

Click here to buy now

<https://pathfinderacademy.in/book/csir-net-life-sciences-combo-with-ecology-11.html>

Connect with Us



TELEGRAM DISCUSSION GROUP

https://t.me/CSIR_NET_Life_Sciences_GATE_BT



<https://www.youtube.com/@Pathfinder-Academy>



<https://www.instagram.com/pathfinderacademy/>



<https://www.facebook.com/PathfinderAcademy.in>