

NINTH EDITION

PART 1

Life Sciences

Fundamentals and Practice

PRANAV KUMAR USHA MINA

Life Sciences

Fundamentals and Practice

Part-1

Ninth edition

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Contents

Chapter 1

Biomolecules and Catalysis

1.1	Amino acids and Proteins	2			
1.1.1	Absolute configuration	5			
1.1.2	Optical activity	6			
1.1.3	Standard and non-standard amino acids	7			
1.1.4	Titration of amino acids	11			
1.1.5	Peptide and polypeptide	17			
1.1.6	Peptide bond	18			
1.1.7	Protein structure	21			
1.1.8	Denaturation of proteins	28			
1.1.9	Solubilities of proteins	28			
1.1.10	Simple and conjugated proteins	29			
1.2	Fibrous and globular proteins	30			
1.2.1	Collagen	31			
1.2.2	Elastin	33			
1.2.3	Keratins	34			
1.2.4	Myoglobin	34			
1.2.5	Hemoglobin	36			
1.2.6	Behavior of allosteric proteins	42			
1.3	Protein folding	43			
1.3.1	Molecular chaperones	45			
1.3.2	Amyloid	46			
1.3.3	Ubiquitin-mediated protein degradation	47			
1.3.4	N-end rule	49			
1.4	Protein sequencing and assays	50			
1.5	Nucleic acids	56			
1.5.1	Nucleotides	56			
1.5.2	Chargaff's rules	60			
1.6	Structure of dsDNA	61			
1.6.1	B-DNA	62			
1.6.2	Z-DNA	64			
1.6.3	Triplex DNA	65			
1.6.4	G-quadruplex	66			
1.6.5	Stability of the dsDNA helix	67			
1.6.6	DNA denaturation	67			
1.6.7	Quantification of nucleic acids	69			
1.6.8	Supercoiled forms of DNA	70			
1.6.9	DNA: A genetic material	73			
1.7	RNA	75			
1.7.1	Alkaline hydrolysis of RNA	76			
1.7.2	RNA World hypothesis	77			
1.7.3	RNA as genetic material	77			
1.8	Carbohydrates	78			
1.8.1	Monosaccharides	78			
1.8.2	Epimers	79			
1.8.3	Cyclic forms	81			
1.8.4	Derivatives of monosaccharide	83			
1.8.5	Disaccharides and glycosidic bond	85			
1.8.6	Polysaccharides	86			
1.8.7	Glycoproteins	89			
1.8.8	Reducing and non-reducing sugar	89			
1.9	Lipids	90			
1.9.1	Fatty acids	90			
1.9.2	Triacylglycerol and Wax	92			
1.9.3	Phospholipids	93			
1.9.4	Glycolipids	94			
1.9.5	Steroid	95			
1.9.6	Eicosanoid	95			
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
4.10	Bacterial toxins	490
4.11	Control of microbial growth	491
4.12	Viruses	495
4.12.1	Bacteriophages (Bacterial virus)	497
4.12.2	Life cycle of bacteriophage	498
4.12.3	Plaques assay	501
4.12.4	Genetic analysis of phage	504
4.12.5	Animal viruses	507
4.12.6	Plant viruses	517
4.13	Prions and Viroids	518
4.13.1	Bacterial and viral diseases	520

Chapter 5

Immunology

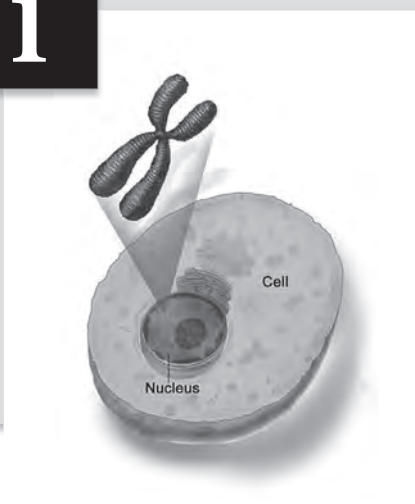
5.1	Innate immunity	523
5.2	Adaptive immunity	529
5.3	Cells of the immune system	531
5.3.1	Common lymphoid progenitor	531
5.3.2	Common myeloid progenitor	533
5.4	Organs involved in the adaptive immune response	535
5.4.1	Primary lymphoid organs	535
5.4.2	Secondary lymphoid organs/tissues	536
5.5	Antigens	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

5.12	Monoclonal antibodies and Hybridoma technology	577
5.13	T cells and cell-mediated immunity	579
5.13.1	Superantigens	592
5.14	The complement system	592
5.15	Hypersensitivity	596
5.16	Autoimmunity	598
5.17	Transplantation	598
5.18	Immunodeficiency diseases	601
5.19	Failures of host defense mechanisms	601
5.20	Vaccines	603

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



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	Macromolecules
Sugars	Polysaccharides
Amino acids	Polypeptides (proteins)
Nucleotides	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.

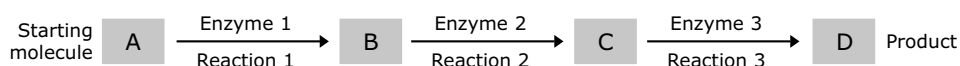


Metabolism

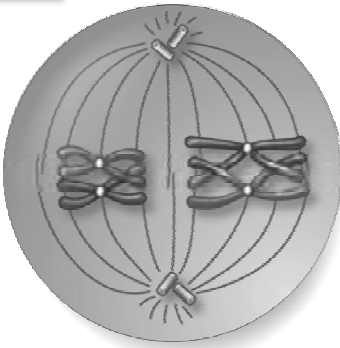
Learning objective

- | | | | |
|-----|---------------------------|------|-------------------------|
| 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.

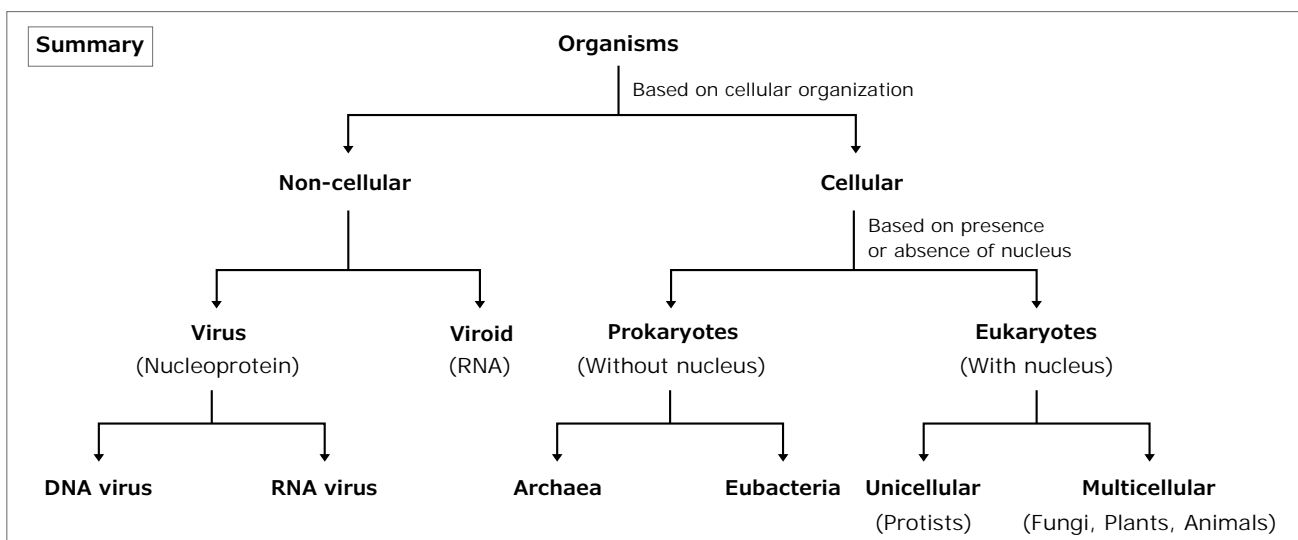


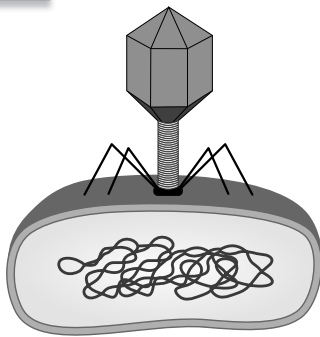
Cell Structure and functions

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.





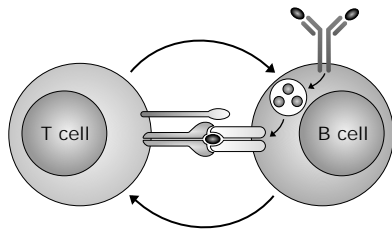
Prokaryotes and Viruses

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

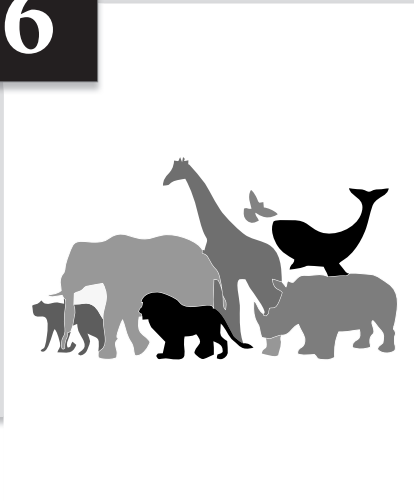
Learning objective

- | | |
|---|---|
| 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

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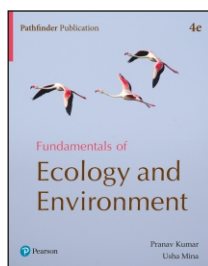
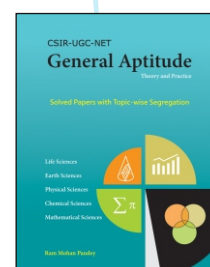
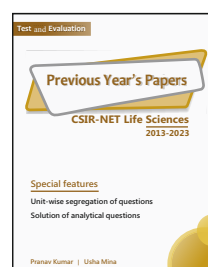
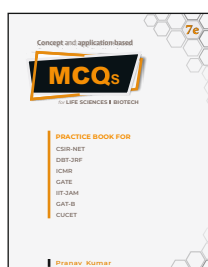
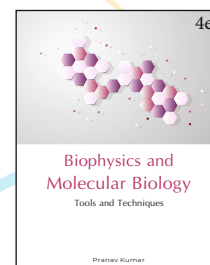
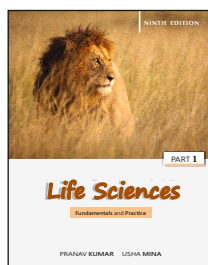
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