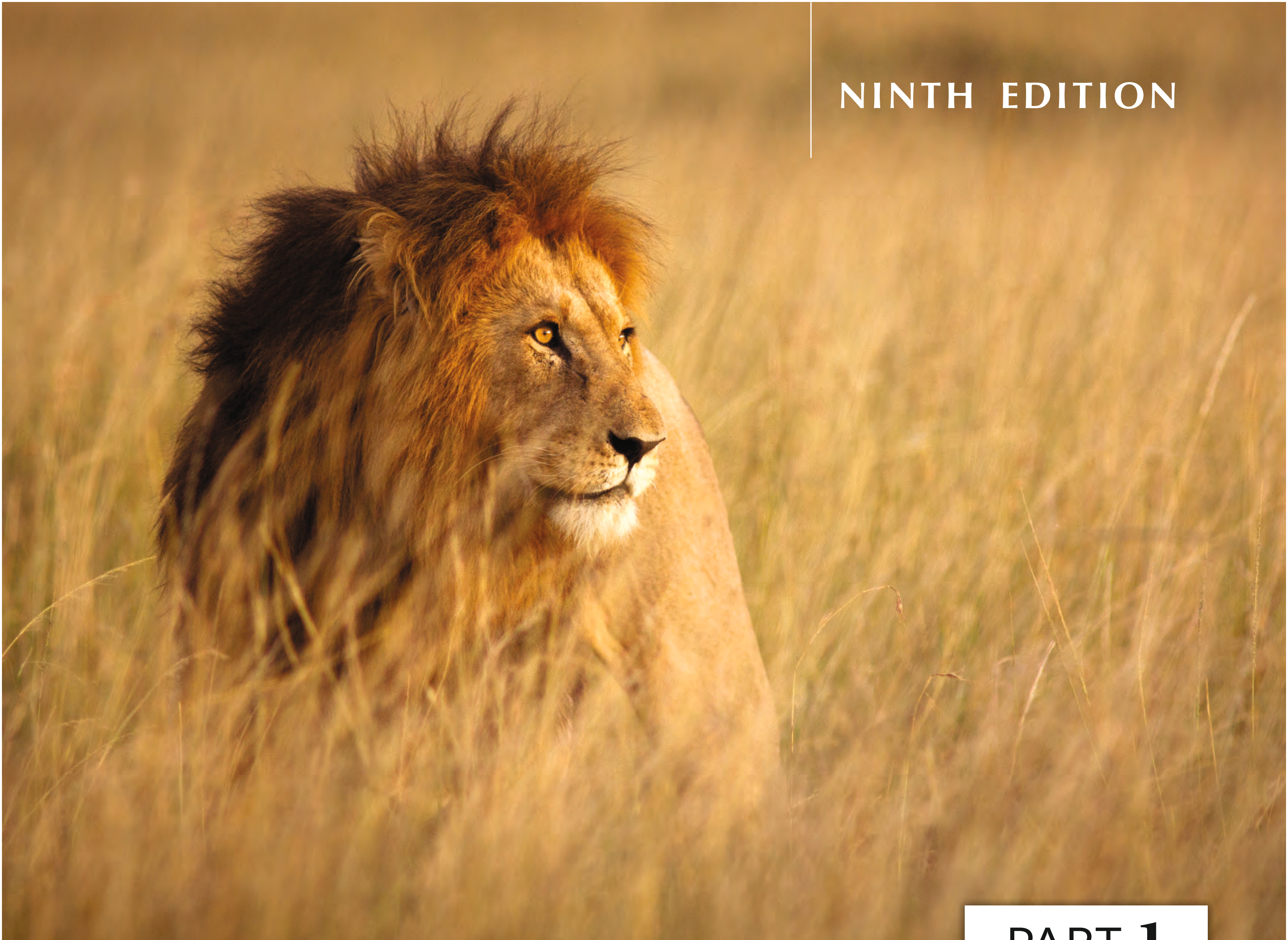

PART 1

Life Sciences

Fundamentals and **Practice**

PRANAV **KUMAR** USHA **MINA**

Life Sciences

Fundamentals and Practice

Part-**1**

Ninth edition

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Life Sciences: Fundamentals and Practice

Ninth edition

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

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

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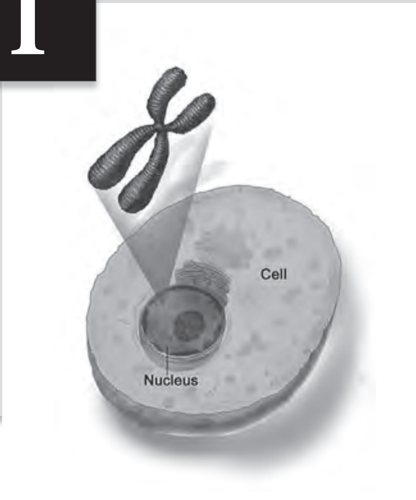

Biomolecules and Catalysis

Learning objective

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.

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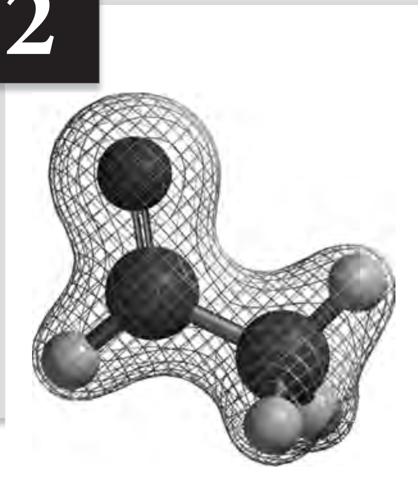
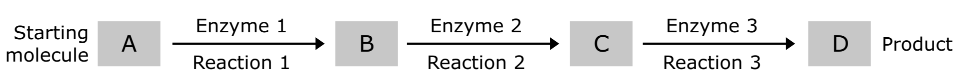


Metabolism

Learning objective

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

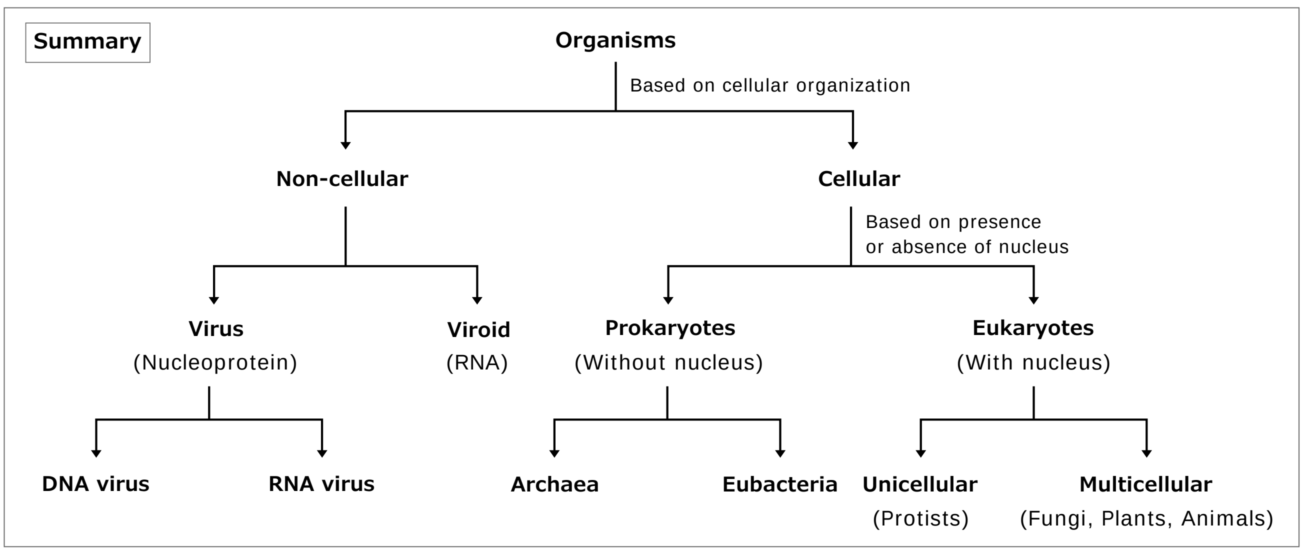
3

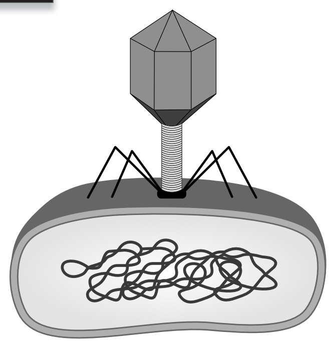
Cell Structure and functions

Learning objective

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





4 Prokaryotes and Viruses

Learning objective

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 *archaebacteria* 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 *Mycoplasma*	Present
Ribosome	70S (cytosol)	80S (cytosol)
Unit-mem. bound organelle	Absent	Present
Cell wall	Present in *most* 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.

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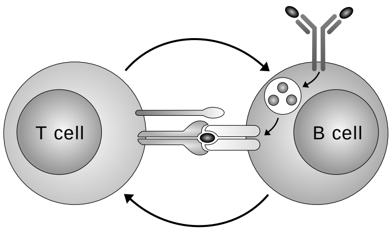


Immunology

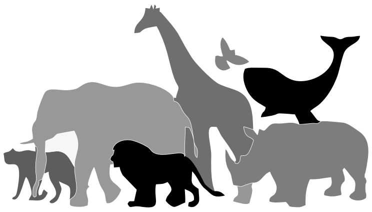
Learning objective

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.

6



Diversity of Life

Learning objective

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.

7

Ecology

Learning objective

7.1 The Environment
7.2 Shelford's law of tolerance
7.3 Ecosystem
7.4 Ecosystem services
7.5 Types of Ecosystems
7.6 Biomes
7.7 Population ecology
7.8 Community ecology
7.9 Island biogeography
7.10 Ecological interdependence and interactions
7.11 Lotka-Volterra model
7.12 Ecological niche
7.13 Effect of competition
7.14 Ecological succession
7.15 Biodiversity
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 that 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 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 2.2_7 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