

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)

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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.

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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

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*.



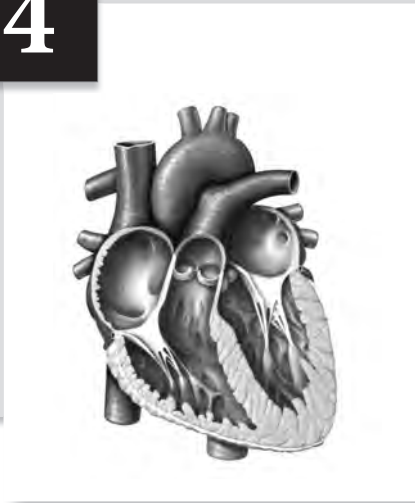
Plant Physiology and Development

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 | 4.6 Cardiovascular System |
| 4.2 Nervous Systems | 4.7 Digestive System |
| 4.3 Sensory organs | 4.8 Excretory System |
| 4.4 Endocrine System | 4.9 Reproductive System |
| 4.5 Respiratory 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

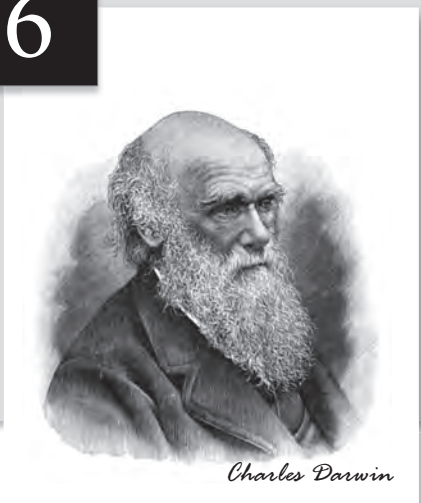
Learning objective

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

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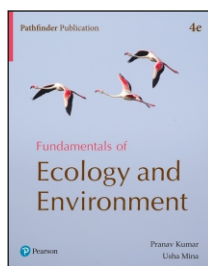
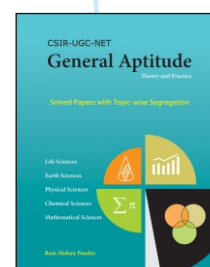
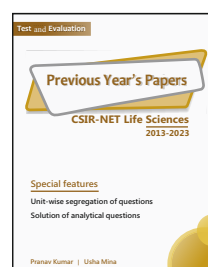
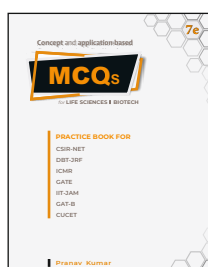
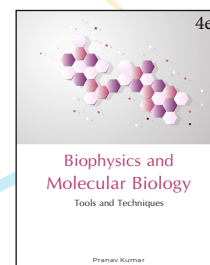
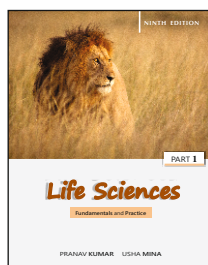
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