Guided Tour

Covers all **important subject areas**

Biophysical Chemistry

What we will Learn

- Understand the basic concept of thermodynamics and its applications in a living system
- The enthalpy, entropy, steady state, free-energy concepts and their application in biological systems
- The various molecular interactions (both strong and weak) existing between different micro and macromolecules of the living system for a desired function could be understood
- The ionization of water, pH, P_{K_a} and buffer and their importance in biological systems can be learned

3.1 PRINCIPLES OF THERMODYNAMICS

In all living systems, there is a constant turnover of materials, and flow of matter in and out of the living system at a steady state. The purpose of this flow is to provide necessary energy for the maintenance of life, both at rest and during activity. The normal activities of living organisms, such as, movement, growth, metabolism and reproduction, demand an almost constant input of energy. Even at rest, organisms devote a considerable portion of their biochemical apparatus, to the acquisition and utilization of energy. The study of energy and its effects on matter falls under the purview of ***thermodynamics***. The word *thermo* has come from temperature, meaning energy, and *dynamics* means the patterns of change or change over time. Thermodynamics is the study of energy changes, accompanying physical and chemical transformations. Although thermodynamics is an area of physical chemistry, it is also applicable to biology. The biological thermodynamics, deals with the study of energy changes accompanied with the internal biochemical dynamics (for example: ATP synthesis, DNA folding, protein folding and stability and other energy-controlled pathways) in a living system. Almost all processes in nature are accompanied by energy changes. This energy is one of the fundamental components of any system and may exist in various forms, like the potential and kinetic energy of a mechanical system, chemical energy, electric energy, thermal energy, radiant energy, etc. These different forms of energy are inter-convertible under suitable conditions.

In this chapter, an attempt has been made to introduce the fundamental concepts of thermodynamics, laws of thermodynamics, enthalpy, entropy, steady state and the concept of free energy in relation to the living system.

Cell Biology

What we will Learn

- The unique master plan of a cell
- The structure of a prokaryotic and eukaryotic cells
- The outer limiting membrane of all animal cells—its structure and function
- The endomembrane system that extends like a network in the cytoplasm, different components of the endomembrane system, the endoplasmic reticulum, Golgi complex and the lysosome
- The energy transformation in a cell and the organelle that is responsible for the same
- The nucleus, nucleus—packaging of genetic material
- The cell cycle, cell cycle regulation
- The programmed cell death or apoptosis and the genetic mechanism that regulates apoptosis

5.1 INTRODUCTION

…ge organisms, regardless of their diversity, have certain biological, chemical and physical characteristics …mon. All, for example, are composed of the same basic units called cells. The cells when analyzed …ally, exhibit similarity in substances that build them, even on each disparate organisms as bacteria and …

…s can be defined as 'small membrane- bound units filled with concentrated aqueous solution of chemi- …d endowed with extraordinary ability to create copies of themselves by growing and dividing into …

…simplest unicellular organisms (say amoeba) exists as a single entity. Unicellular organisms are the …e organisms that live in different types of environment. They adapt to the environment, make copies …rvive to survive.

…s may also form multicellular organisms, in which case they become differentiated, specialised and …ent different functions for the organism. The cells within the multicellular organism communicate …

Gene-Product Engineering

What we will Learn

- Manipulation of gene to get the desired product
- Important methods of protein engineering
- Different methods of site-directed mutagenesis

12.1 INTRODUCTION

Molecular biology aims at manipulation of DNA (gene) to get the desired product. DNA produces proteins via RNA. The main product which influences the biological system and is directly or indirectly involved in producing a product of human interest is *protein*. Molecular tools help to manipulate … protein. This concept is known as *protein engineering*.

12.2 PROTEIN ENGINEERING

There are two general techniques used to get an engineered protein. They are

1. The rational approach
2. Directed evolution

1. Rational Approach

There are two variations in the rational approach. One of the variations is the cas… proteins and identification of the sequence by which there is a difference in functional… mutagenesis, one can change such a desired residue to evaluate the function. The sec… nal approach deals with the three-dimensional structure of protein. Based on the stru… residues are selected for mutagenesis. The effect of change of residue on biological …

Plant Biotechnology

What we will Learn

- Basic idea of plant–tissue culture and concept of totipotency
- Designing of a plant–tissue culture laboratory
- Preparation of culture media
- Use of aseptic culture technique
- Methods of selection, isolation and maintenance of callus culture
- Methods of initiation and maintenance of isolated cells in cell suspension …
- Somatic embryogenesis and its application
- Concept, procedure and application of organ-culture and embryo cu…
- Technique, culture and fusion of protoplasts
- Somatic cell hybridization and formation of cybrids
- Application of the plant-tissue culture in the field of basic and applie…
- Strategies and applications of gene–transfer technology in plants

14.1 INTRODUCTION

Biotechnology has modified human life. For wider applicability and research, the term … groups of the organisms, environment and other issues like plant biotechnology, animal bi… biotechnology, environmental biotechnology, etc. The importance of plant biotechnolo… as it produces novel organisms with enriched qualitative and quantitative characters… easily worked out in plants and such genes are successfully expressible in plants bec… totipotency—each cell has the potentiality to give a plant. This is possible for a well-…

DNA Replication, Repair and Recombination

What we will Learn

- Basic steps of DNA replication
- Experimental evidence for semiconservative replication
- Bidirectional replication
- Phases of DNA replication
- Importance of DNA polymerase III
- The replication machine—replisome
- Priming apparatus—primosome
- Difference between prokaryotic and eukaryotic replication
- Need of DNA repair system
- Types of DNA repair system
- Causes of DNA damage
- Importance of exchange of DNA segment
- Types of recombinations at molecular level
- Mechanism of transposition

7.1 DNA REPLICATION

Inheritance is a common phenomenon in the biological world. The inheritable character has to be copied exactly and passed from the parents to the offspring, generation after generation. The method of having an exact copy and transfer of the same was not clearly known till the development of concepts such as 'chromosomes are bearers of heredity', 'gene is the unit of heritable character' and 'DNA is the genetic material'. The elucidation of 'DNA as the genetic material' and deciphering of DNA as the double helical structure, clarified the method of copying and transfer of genetic information coded on the DNA.

Molecular Markers and Genome Mapping

What we will Learn

- Different molecular markers of the genome
- Characters of molecular marker
- Different molecular markers such as RFLP, SSLPs, SNPs, and their role as markers for genetic map
- Molecular genome mapping by genetic technique
- Genome mapping by physical techniques such as FISH

19.1 MOLECULAR MARKERS

With the advent of recombinant DNA technology in the 1970s and PCR t… efforts were made to develop the molecular maps of the genomes of several… lar markers. Molecular markers are the existing variations at DNA level an… polymorphisms in DNA sequences (i.e. base–pair deletions, substitutions… superior to other forms of markers (such as morphological or phenotypic… because the molecular markers are relatively simple to detect, abundant th… independent of environmental conditions and can be detected at any stage…

An ideal molecular marker must have the following desirable character…

(i) It must be polymorphic so that diversity can be measured.
(ii) It should be randomly and frequently distributed throughout the p…
(iii) It must distinguish between homozygotes and heterozygotes.
(iv) It should be easy and economical to use.
(v) It should be highly reproducible.
(vi) It should be non-epistatic.
(vii) It should be multi-allelic.

Animal Biotechnology

What we will Learn

- Advantages and limitations of tissue culture
- Equipments required in a tissue-culture laboratory and their utility
- Methodology of handling and starting tissue culture
- Media and serum, their physical and chemical nature
- Quantization procedure, growth cycle and cell-cycle estimation
- Stem cells and their application in medical and agriculture research
- Somatic-cell fusion, selection of hybrids, and mapping of chromosome u… fusion protocol

13.1 INTRODUCTION

Tissue culture is often used as a generic term that refers to both organ culture and cell cultur… culture is a technique in which the tissues, cells or organs are grown and maintained in … outside the organism. The technique of tissue culture was first devised at the beginning … century. From 1907 to 1960, the technique was in a developing stage and growing at a ver… from 1970 onwards when the technique was standardized and established, scientists start… cells in vitro.

At present, tissue culture is an indispensable tool, particularly in the fields of medical … research.

13.2 ADVANTAGES OF TISSUE CULTURE

The major advantage of tissue culture is the control of the physiochemical environment wh… growing. The environment can be kept relatively constant, unless natural products like seru…

Immunotechnology

What we will Learn

- Basics of monoclonal antibodies
- Hybridoma technology leading to the production of monoclonal antibodies
- Wide advantages and application of monoclonal antibodies in different areas of biology medical, clinical diagnosis and research
- Technique of antibody engineering and alternatives to hybridoma technology
- Production human antibodies and use of phase–display technology

17.1 IMMUNOTECHNOLOGY

In the previous chapter, we have discussed the immune system, which provides immunity (i.e. the power to fight disease-causing organisms) in animals. In this connection, antigen–antibody structures and their interactions have been discussed. For human health care, the subject of the production and use of antibodies has become a very important area of research, not only for academic interest but also for its relevance to the industrial growth for the production of drugs and vaccines for diagnostic and therapeutic uses. Generally, antibodies prepared from serum will not have the desired specificity and, therefore, cannot be utilized for diagnostic or screening purposes. On the other hand, monoclonal antibodies (Mabs), being homogenous and of desired specificity, can be utilized for diagnosis and screening with ease and certainty. Thus, the discovery, production, genetic manipulation i.e. the antibody engineering, and uses of these Mabs will be discussed in this chapter. In addition, the basic technique, commonly known as *hybridoma technology* involved in Mabs, has also been elaborated in this chapter.

For many years, antibodies or immunoglobulins, produced by the B lymphocytes have been known to play a major role in the diagnosis of a wide variety of diseases. Currently, immunologic assays are extensively used … and quantify drugs, bacterial and viral products, tumour antigens … assays have been complicated because of antibodies of restricted … obtained by conventional methods. Such an antisera, secreted by

Industrial Microbiology

What we will Learn

- Biotechnological importance of microorganisms
- Microbial products essential for human welfare that can be produced on industrial scale
- Importance and production of single-cell protein
- Use of microbes as biofertilisers

21.1 INTRODUCTION

The study of microorganisms for their use and growth on a large scale to obtain val… by the way of chemical transformation is called *industrial microbiology*. The sta… ogy dates back to the ancient times when beer and wine making fermentation pr… Presently the area of industrial microbiology is expanded to pharmaceutical, foo… enzymes and vitamin. With the advent of biotechnology the discipline industrial … new approach known as *microbial biotechnology*. The products obtained in a con… come of metabolic reactions of microorganisms. In microbial biotechnology gen… responsible for such metabolic reactions are manipulated to enhance the metaboli…

21.2 BIOTECHNOLOGICAL IMPORTANCE OF MICROORG…

Biotechnology is basically meant for human welfare. It meets the ever-increasing … products in a sustainable way. Biotechnology, in its true sense, can be traced back … milk, grains and plant juice were processed to get different products. The process … by microbes and such a microbial process is known as *fermentation*. From the beg… tion, humans have used fermentation carried on by microbes to produce milk pr… microbes have been targeted from time immemorial to produce product on a larg… biotechnology, microbes are still at the top of the list of living organisms used in … cellular products. Besides production of different food products by microbial ferme… for production of alcohols, vitamins, organic acids, ketones, enzymes, antibiotics, … mitigate the environmental problems biotechnologically (Table 21.1).

Environmental Biotechnology

What we will Learn

- Recollect the structural and functional components of an ecosystem—ecological imbalance that leads to different pollution
- Control of environmental pollution through biotechnology strategy
- Waste water and solid waste treatment by using microorganisms
- Use of biopesticides and their mode of action
- Bioremediation
- Global environmental problems

23.1 INTRODUCTION

Environment is the physical, chemical and biological condition of a region … physical components of environment include the atmosphere, land and water… the great chemical cycles that flow through the physical and biological system… are the living organisms starting from microorganisms, plants, animals to ma… environment for their activities of life and adapt accordingly.

The environment is dynamic. Millions of years ago, when the earth was y… earth was different from what we see today. The climate has changed, rivers … forms which existed then are not seen today—many have disappeared many ag…

A few thousand years ago, humans originated somewhere in South Africa, … free hands and a developed brain the human race has been ruling this earth. W… environment conditions successfully—so as a result, our number is increasing…

Today, the worlds human population is estimated to be over six billion. Th… lation is continuously increasing. In the last 10,000 years, the population of … thousand fold. This phenomenal growth in population has put pressure on the e… it out of balance with the environment. The interaction between the human … very complex and dynamic. As the population grows, the level of consump… production of wastes proportionately increases.

Genomics and Proteomics

What we will Learn

- Concept and types of genomics
- Various steps of genome sequencing necessary for any genome project
- Location and prediction of a gene
- Functional genomics and its tools
- Determination of function of unknown genes
- Technology of DNA microarray
- Proteomics, different areas of proteomics and its applications
- Current research with some important websites on proteomics and bioinformatics for further reference

26.1 GENOMICS

Genomics is a rapidly emerging area of research, which came into existence towards the end of the 20th century and promises to become the dominant theme of intellectual activity in the coming decades, revolutionizing our understanding of biology. The word 'genomics' was coined by Thomas Roderick in 1986. Genomics can be defined as 'the study of molecular organization of genome, i.e. how genes and genetic informations are organized within the genome and how this organization determines their function.'

It is a large field that embraces the study of whole genome (the haploid set of chromosomes of an eukaryotic organism or the entire genetic complement of a prokaryote is known as genome) of the living organisms, their physical and molecular organization, evolution and functions of the myriad of constituent genes. There are three components of genomics: 1) *structural genomics*, 2) *functional genomics*, 3) *comparative genomics*. Structural genomics deals with sequencing and mapping of genomes and a study of the structure of all gene sequences encoded in a fully sequenced genome. Functional genomics involves a study of the functions of all specific gene sequences and their expression in time and space in an organism. *Comparative genomics* deals with the comparative study of genomes of different organisms to find the degree of similarity or relatedness that exists between genomes of related species or genera and hence to establish the evolutionary relationship existing between them.

The **'What You will Learn'** *section at the beginning of every chapter gives an overview of the topics to be learnt*

What we will Learn

- Advantages and limitations of tissue culture
- Equipments required in a tissue-culture laboratory and their utility
- Methodology of handling and starting tissue culture
- Media and serum, their physical and chemical nature
- Quantitation procedure, growth cycle and cell-cycle estimation
- Stem cells and their application in medical and agriculture research
- Somatic-cell fusion, selection of hybrids, and mapping of chromosome using somatic cell fusion protocol

There are three types of restriction enzymes.

1. Type I

These type of restriction enzymes are complex with different sub-units. The enzymes recognise a 15 bp DNA sequence but do not produce a cut within this sequence. The cleavage occurs far away from the recognition site, which may be approximately 1000 bp downstream. The enzymes require ATP, Mg^{2+} and s-Adenosyl methionine as cofactors. These enzymes are not much in use in gene manipulation.

Box 11.3

Case study 2

Discovery of restriction and modification system

Bacteria have the characteristic to destroy incoming DNA, if it is recognised as foreign. When bacteria in a colony are infected with bacteriophage, lysis occurs, thereby causing plaque formation. If the incoming DNA is a bacteriophage DNA the effect is to reduce the number of plaques formed in a plating test, i.e. the effect is to reduce the Efficiency Of Plating (EOP). The phenomenon of restriction and modification were illustrated by the behavior of phage λ on two *E. coli* host strains.

The λ phage grown upon *E. coli* strain C when titred upon *E. coli* strain K, the efficiency of plating (EOP) is reduced by several orders of magnitude than that of *E. coli* C. It means the phage is *restricted* by *E. coli* strain K. The phages that do result from the infection of *E. coli* strain K are titred upon *E. coli* strain K, and there is no reduction of efficiency of plating, i.e., the phage DNA is no more restricted. But if plated on *E. coli* strain C, there is reduction of plating efficiency. This nonheritable change conferred upon the phage by the second host strain (in this case *E. coli* strain K), that allows it not to be further restricted by the strain is called *modification*.

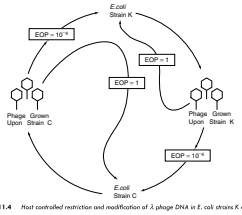


Fig. 11.4 *Host controlled restriction and modification of λ phage DNA in E. coli strains K and C*

Industry Orientation and Application Orientation

Industrial linkages through CASE STUDIES

Biotechnology laboratory techniques: PCR, Electrophoresis, Chromatography, RDT and Genetic Engineering

28

Basic Experiments

What we will Learn

- Culture of microbes
- Preparation and maintenance of pure culture
- Characterisation of microbes
- Isolation, pureline culture and characterisation of amylase producing microbes
- Extraction and characterisation of DNA
- Extraction and characterisation of protein
- Tissue culture

28.1 LIST OF EXPERIMENTS

1. To culture microbes in our environment
2. To isolate microbes by streak-plate method
3. To prepare and maintain pure cultures
4. To culture microbes supposed to be industrially important in a mixed culture from different natural sources
5. To isolate strains differing morphologically in colony characters from mixed culture by streak plate
6. To prepare and maintain pure cultures of isolated strains
7. Screening of better strains among isolated strains for amylase activity
8. To culture isolated pure-line strains in broth
9. To characterise and maintain the pure culture of selected strain for amylase activity
10. To study the growth of bacteria in broth by haemocytometer count
11. To find the generation time of pure culture strains isolated from rice water
12. To study the growth of selected strain for amylase activity by spectrophotometric method
13. To study the growth of selected strain for amylase activity in media supplemented with different carbon sources
14. Separation of commercially available DNA and extracted DNA by agarose gel electrophoresis
15. Separations of extracted plant and animal proteins by SDS-PAGE
16. To isolate and characterize bacterial genomic DNA
17. To find the effective duration of sterilization to have axenic culture of carrot cambial tissue

Summary

- Enzymes are *protein catalysts* that regulate the rate of physiological and biochemical processes of living cells.
- They catalyze reactions involving group transfer, isomerization, oxidoreduction or synthesis of covalent bonds.
- Based on the type of reaction, enzymes have been classified into six classes (oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases).
- Enzymes require the assistance of nonprotein *coenzymes* which are mostly B-vitamin derivatives. Cofactors like metal ions also participate in enzyme-catalyzed reactions.
- Most enzymes are highly specific for their substrates, coenzymes and the types of reactions catalyzed.
- Enzyme activity is measured through techniques like *spectrophotometry* and *electrophoresis*. Precise intracellular location of enzymes is done through histochemical and cell-fractionation techniques.
- While almost all enzymes are proteins, catalytic RNAs known as *ribozymes* catalyze specific hydrolysis of phosphodiester bonds in RNAs. *Abzymes* are monoclonal antibodies which in addition to their immunological functions also participate in catalytic reaction.
- The rates of enzyme-catalyzed reactions are regulated by temperature, pH, enzyme concentration and substrate concentration. Activators and inhibitors are also involved to accelerate or inhibit enzyme-catalyzed reactions.
- Enzymes alter reaction rates by *lowering the activation energy,* for the formation of **transition** *state* and by providing amino acid residues whose functional groups perform specific roles in catalysis at a site, known as *active site or catalytic site*.
- *Regulation* of enzyme activity contributes in a major way to preserve homeostasis. As a result, a relatively constant intracellular and intraorganismal environment is maintained in spite of wide fluctuations in external environment (e.g. temperature).
- The extensive use of enzymes in various fields is the result of *enzyme* technology. This area embraces production, isolation, use in purified form and *immobilization* of enzymes. The culture of microorganisms is done in suitable media and the required enzymes are isolated using various methods.
- Immobilization involves attachment of enzymes on insoluble polymers, membranes and particles which act as support or carrier for enzyme activity.
- Immobilization permits reuse of the enzyme after the completion of reaction and formation of products.
- Enzymes are used for therapeutic purposes such as diagnosis of diseases and *enzyme therapy.* They are extensively used in different industries (e.g. dairy, textile, leather, brewing, detergent, etc.).
- Enzymes are useful in the construction of *biocensors* and *biochips.* They also play a role in pollution control and genetic-engineering techniques.

Each chapter has an extensive **Summary** *for quick recapitulation of the concepts discussed.*

- *More than 600* **illustrations and diagrams** *are present to enhance the concepts.*
- *Select* **Colour figures** *add greater clarity to the subject.*

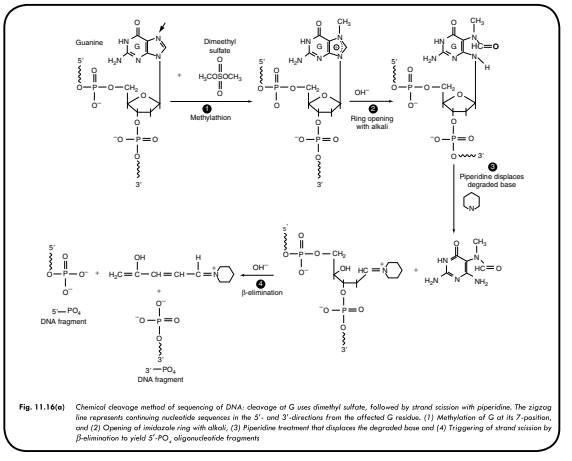


Fig. 11.16(a) *Chemical cleavage method of sequencing of DNA: cleavage at G uses dimethyl sulfate, followed by strand scission with piperidine. The zigzag line represents continuing nucleotide sequences in the 5′- and 3′-directions from the affected G residue. (1) Methylation of G at its 7-position, and (2) Opening of imidazole ring with alkali, (3) Piperidine treatment that displaces the degraded base and (4) Triggering of strand scission by β-elimination to yield 5′-PO_4 oligonucleotide fragments*

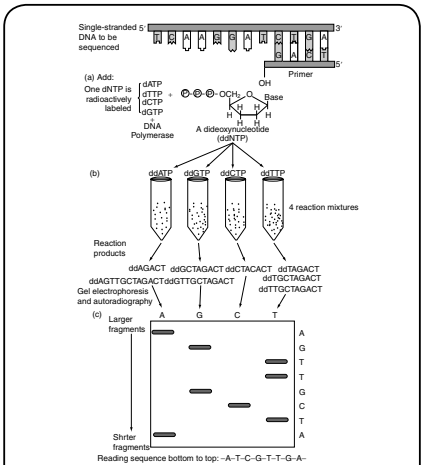
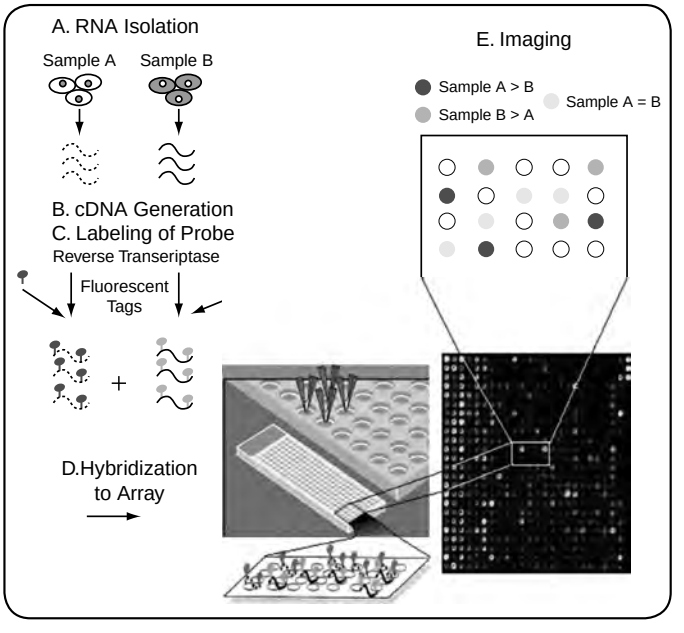


Fig. 11.18 *The dideoxy method of DNA sequencing. (a) DNA polymerase reaction. (b) Four reaction mixtures with nucleoside triphosphates plus one dideoxynucleoside triphosphate. (c) Electrophoregram. The nucleotide sequence is read from the bottom to the top of the gel*



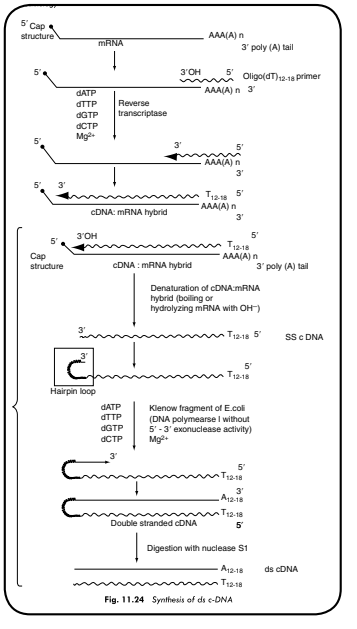


Fig. 11.24 *Synthesis of ds c-DNA*

Graded chapter-end questions patterned as per university examinations

- **Long-answer questions** *to test the student's subjective grasp on the topics*
- **Short-answer questions** *to test the student's hold on terms and definitions.*
- **Objective-type questions** *for quick revision and recapitulation of concepts*

(A) Long–answer Questions

1. In what way are cells *in vitro* different from cells *in vivo*? What are the major hurdles in growing cells *in vitro*?
2. Design a tissue-culture laboratory. List some major equipment and their uses in a tissue-culture laboratory.
3. While preparing the medium for tissue culture, what physical and chemical parameters should be taken into account? Why are such parameters important?
4. For enzymatic disaggregation which enzyme is most preferred? How can you minimize tissue damage while carrying out enzymatic disaggregation?
5. Give an account of the biology and characters of the cultured cell.
6. Why is it necessary to preserve cells? Describe the method of cell preservation.
7. Discuss the therapeutic use and classification of stem cells.
8. Give an account of aseptic techniques and sterilization procedures for tissue culture.
9. Explain the role of carbon dioxide in maintaining cells *in vitro*.
10. What are major constituents of serum? Why is serum essential in setting some culture? What are its limitations?

(B) Short–answer Questions

1. What are the optimum pH of culture medium for proper cell growth? Which indicator is commonly used to measure the pH?
2. In a tissue-culture laboratory, what are the different types of microscopes essential and why?
3. Why should you insert a cotton plug on the top of a glass pipette before you sterilize it?
4. What are the disadvantages of inclusion of serum in a medium?
5. How does colchicine help in synchronizing cells?
6. Name at least three agents for cell fusion.
7. Name commonly used cryopreservatives.
8. Explain the terms 'cell line' and 'passage'.
9. Name four commonly used commercially available culture media.
10. What are the different phases of cells when they are in a culture medium?

(C) Fill in the Blanks

i. RNA polymerase holoenzyme consists ——— number of α sub-units.
ii. The subunit composition of RNA polymerase holoenzyme of prokaryote is written as ———.
iii. The closed promoter complex is formed due to the formation of complex between RNA polymerase and ——————— sequence of DNA.

(D) Multiple choices. Choose the correct answer.

i. The transfer RNA – $tRNA_f^{met}$ is able to read the sequence
   a. AUG, GUG, UUG
   b. AAG, GUG, UUG
   c. AAG, GGA, UUG
   d. AUG, GUG, CCG
ii. Number of RNA polymerases marked in eukaryotic cells are a-2, b-3, c-4, d-5

Glossary

Acid: A substance that can donate a proton (H^+)

Activation energy ($\Delta G^{\ddagger}$): The amount of energy (in joules) required to convert all the molecules in 1 mole of a reacting substance from the ground state to the transition state.

Active immunity: Immunity created by a person's own immune system by producing antibodies against infectious agents, e.g. exposure to infectious agents or immunization

Active site: The region of an enzyme surface that binds the substrate molecule and catalytically transforms it; also known as catalytic site

Adaptive immunity: An acquired immunity having characteristics of specificity, diversity, memory and discrimination between self and non-self

Adaptor: A synthetic double-stranded oligonucleotide, blunt-ended at one end and having a nucleotide extension at the other that can base pair with a cohesive end created by cleavage of DNA molecule with restriction endonuclease II

AFLP (Amplified Fragment Length Polymorphism): A combination of RFLP and RAPD; very sensitive in detecting polymorphism in a genome

Agar: A gelatinous polysaccharide that forms a gel with water and solidifies when allowed to stand at room temperature; used extensively as a culture medium for the growth of bacteria and fungi; derived from some red algae of the genus Gelidium, Gracilaria, Gigartina, Ahnfeltia

Alcohol fermentation: The anaerobic conversion of glucose to ethanol via glycolysis

Allele: Alternative form of a gene

Allosteric site: The specific site on the surface of an allosteric enzyme molecule to which the modulator or effector molecule is bound

Amphibolic pathway: A metabolic pathway used in both catabolism and anabolism

Amphoteric: Capable of donating and accepting protons

Antibiotic: A biologically or synthetically produced chemical substance that inhibits growth microorganisms, e.g. penicillin or streptomycin; most antibiotics are not lethal to viruses

Antibody: A protein produced by the immune system of an animal in response to a foreign substance called antigen; also known as immunoglobulin (I_g); each antibody molecule is composed of 4 sub-units of two heavy chains and two light chains

Antibody: A protein (immunoglobulin) synthesized by a B lymphocyte and recognizes a specific site on an antigen

Antigen: A compound that induces the production of antibodies; it elicits an immune response when introduced into an animal, and is specifically recognized by an antibody

Assay: A test to detect the presence of some substances in a small amount in solution

A **Glossary** *is provided at the end of the book to help students look up the definitions of important terms and concepts.*