# MODULE 1 : Introduction to study of man

## Biochemistry – Undergraduate Programme

**Faculty of Medicine and Allied Sciences**
**Rajarata University of Sri Lanka**

### 1 Origin of Life

#### 1.1 Primordial Soup

1.1.1 Review the evidence that support evolution of life.
1.1.2 Recall the conditions that may have been present on the primitive earth favorable for the formation of biomolecules.
1.1.3 Describe the experiments carried out that simulated the conditions on primitive earth.
1.1.4 Recall that amino acids, purines, pyrimidines, sugars, glycerol, fatty acids, and choline were the precursors of macromolecules that emerged later.
1.1.5 Recall that the environmental conditions have changed from reducing to oxidizing state and the importance of $O_2$.
1.1.6 Recall that evolutionary process was a product of time & energy and those organisms that emerged used more and more selective fuels.

#### 1.2 Chemical Evolution

1.2.1 Recall the most abundant elements likely to have been present following the big bang.
1.2.2 Likely reasons for selection of specific elements to form biological molecules.
1.2.3 State the likely biological macromolecules that resulted from chemical evolution.
1.2.4 Explain the rationale for the formation of bio-macromolecular complexes.
1.2.5 Appreciate that cell organelles are assembled using macromolecular complexes
1.2.6 Identify molecular complexes found in the nucleus, ribosome and the membrane.

#### 1.3 Biological Evolution

1.3.1 Recall that chemical evolution resulted in the production of self replicating biomolecules, RNA and protein.
1.3.2 Explain the central dogma DNA -----> RNA ------> Protein.
1.3.3 Explain the necessity for DNA to have emerged as the bio-macromolecule of the highest order.
1.3.4 Deduce the type of interaction that maintains the structure of chromosomes, ribosomes and biological membranes.
1.3.6 Describe the different ways by which functional efficiency of the cell has been achieved.

## 2 Prokaryote and Eukaryotes

2.1 Know that they are the two most diverse forms of living cells, as reflected by their cellular constitution.
2.2 Know the constituents of the two types of the cells & their functions.
2.3 Know that a prokaryotic cell carries out functions of a eukaryotic cell, but at a lower level of internal organization.
2.4 Be aware that proteins synthesised in eukaryotes undergo modifications not seen in prokaryote & its significance in the manufacture of polypeptide hormones.

## 3 Cell Organelles

### 3.1 Nucleus

3.1.1 State the chemical components of chromosomes.
3.1.2 Recall that chromosomes are located in the nucleus.
3.1.3 Recall that the genetic material controls the cytoplasmic activity and influences the activity of cell membrane.
3.1.4 Explain how the nuclear sap and cell sap are in communication.
3.1.5 Recall that major chromosomal proteins are basic in nature and that they interact with phosphate groups of DNA.
3.1.6 Recall that acidic proteins are present in the chromosomes and that they have a regulatory function.
3.1.7 With the aid of a series of diagrams, explain 'semi-conservative' replication of DNA.
3.1.8 List the substances required for the synthesis of new DNA in the cell.
3.1.9 Recall the number of chromosomes in the human cell.
3.1.10 Describe the distribution of the different elements on the DNA and their possible functions.

### 3.2 Endoplasmic Reticulum

3.2.1 Name the two types of endoplasmic reticulum found in the cell.
3.2.2 State the relationship between these two types on the basis of the components of the endoplasmic reticulum.
3.2.3 Recall that the differences between the two types are not so great as to prevent one from being transformed to the other.
3.2.4 Compare the membrane of the endoplasmic reticulum with the cell membrane.
3.2.5 Recall the relationship between the nuclear membrane and the cell membrane.
3.2.6 Recall the parts of a ribosome and their functions.
3.2.7 Recall the functions of the rough endoplasmic reticulum.
3.2.8 Give examples of cell types to show the relationship between their secretory activity and the abundance of rough endoplasmic reticulum.
3.2.9 State the organelle responsible for making protein for use in the cell itself.
3.2.10 Recall the functions of the smooth endoplasmic reticulum.
3.2.11 Give examples of cell types to show the relationship between relative

abundance of RER and SER and its function.

3.2.12 Explain the term microsome.

### 3.3 Golgi Apparatus

3.3.1 Recall the usual shape & location of the Golgi apparatus as seen under the electron microscope.

3.3.2 Compare the unit membrane of the Golgi apparatus and the cell membrane.

3.3.3 Explain how the Golgi apparatus helps in the conservation of intracellular proteins.

3.3.4 State the possible modifications undergone by proteins in the Golgi.

### 3.4 Lysosomes

3.4.1 Identify a lysosome in an electron micrograph.

3.4.2 Recall the functions of lysosomes.

3.4.3 State why it is necessary for some enzymes to be enclosed within a membrane while within the cell.

### 3.5 Mitochondria

3.5.1 Draw the ultrastructure of a mitochondrion.

3.5.2 Compare the mitochondrial membranes with the cell membranes.

3.5.3 Know how ATP, H of NADH, citrate, malate, fatty acids and Acetyl CoA are transferred through the mitochondrial membrane.

### 3.6 Cytoplasm

3.6.1 Recall that, though simple in structure, the cytoplasm is non-homogenous.

3.6.2 Recall that, it accommodates many metabolic reactions that are closely related and are primitive in origin.

3.6.3 List the main metabolic reactions occurring in the cytoplasm and the suitability of their location, if any.

3.6.4 Explain the supportive role of cytoplasm in protein synthesis.

3.6.5 Recall that all cell organelles are immersed in the cytoplasm and that changes in calcium and cAMP concentration result in regulated alteration of their metabolism.

## 4. Internal Environment of the Cell

4.1 Know how genetic and environmental factors (nutrition and pollution) affect internal environment.

4.2 Describe how the internal environment is maintained structurally by compartmentalization with membranes and cytoskeleton (protein), and how deficiency leads to disease.

4.3 Explain how pH, osmotic pressure, electrolyte balance and energy metabolism affect the maintenance of the functional integrity of the internal environment.

4.4 Recognize the chemical components of cells i.e. water, inorganic ions, small

organic molecules & macromolecules.

4.5 Explain the importance of unique physicochemical properties of water, which makes life possible
- 4.5.1 Recall the formation of hydrogen bonds between water molecules and its importance.
- 4.5.2 Recall the chemical basis and importance of solvent properties of water.

4.6 Describe the differences in the dissociation of electrolytes, weak electrolytes and non-electrolytes.

4.7 Recall that many biologically important molecules are weak acids or bases.
- 4.7.1 Recall the Lowry-Bronsted definition of an acid and a base.
- 4.7.2 Know important conjugate acid-base pairs in biological systems.
- 4.7.3 Know the Henderson-Hasselbalch equation and calculations based on this equation.

4.8 Learn the importance of buffering to control pH with examples (bicarbonate, phosphate and proteins, inclusive).

4.9 Know how macromolecules (protein) and micromolecules (inorganic molecules, amino acids, sugar and peptides) maintain osmotic pressure.

4.10 Know how Na/K-pump and ion channels (Na, K, Ca, and Cl) maintain electrolyte balance in the cell.

4.11 Know how energy metabolism is regulated by ATP/AMP+ADP and NADH/NAD ratio.

4.12 List the markers that measure the function of different cell organelles in the internal environment.

## 5. Cell Membrane

### 5.1 Structure and Function

- 5.1.1 Draw and label the molecular components of the cell membrane.
- 5.1.2 Explain how the alteration of the fatty acid composition and cholesterol content may alter the structure and hence the functions of the membrane.
- 5.1.3 Describe the different location of proteins on the cell membrane and their possible functions.
- 5.1.4 Recall the major differences in the composition and the structure of the nuclear membrane, inner mitochondrial and outer mitochondrial membranes.
- 5.1.5 Recall the differences in the transport of molecules through the different types of membranes in the cell.
- 5.1.6 Recall that the concentration of Na and K inside and outside a cell is different.
- 5.1.7 Explain the need for a special mechanism by which a cell can pump out Na and bring in K.
- 5.1.8 Recall that the Na/K pump is the main energy using process in the resting cell.
- 5.1.9 Explain the mechanism of action of cardiac glycosides.
- 5.1.10 Explain the term osmosis.
- 5.1.11 Be aware of the importance of membranes in osmosis.
- 5.1.12 Understand the principles involved in the formation of oedema,

osmotic diuresis and the use of osmotic laxatives.

5.1.13 Know that cholera toxin promotes secretion of Na+ and Cl- via cyclic AMP and causes diarrhoea.

### 5.2 Membrane Transport

5.2.1 Explain the need for selective transport across the lipid bilayer.

5.2.2 Explain diffusion, facilitated diffusion and carrier mediated transport, giving examples of each.

5.2.3 Name the mode of transport which is dependent upon hydrolysis of ATP, giving reasons.

5.4.4 Explain the term, phagocytosis, pinocytosis & exocytosis (reverse pinocytosis).

5.2.5 Explain the functions of intracellular structural elements of the membrane.

## 6. Cell Constituents

### 6.1 Carbohydrates

6.1.1 List the characteristic features of a carbohydrate, a mono, a di, and polysaccharide, an aldose, a ketose, an aldohexose, a ketohexose, a pentose and a triose, giving one example of each.

6.1.2 Perform and describe tests to identify glucose, fructose, lactose, maltose, sucrose, glycogen and starch.

6.1.3 Recognise the differences between dextro and levo rotatory forms, D and L forms, alpha and beta forms and alpha-D-glucopyranose and beta-D- fructofuranose.

6.1.4 Recognise the structures of glucose, fructose, galactose, maltose, sucrose, lactose, amylose and amylopectin.

6.1.5 List the components of heparin, hyaluronic acid and chondroitin sulphate.

6.1.6 Know the functions and locations of glycoproteins, proteoglycans, peptidoglycans and glycolipids.

6.1.7 Know the composition of the ground substance in connective tissues.

6.1.8 Know the structures and functions of starch, glycogen, cellulose, lactose, glucose, fructose & mucopolysaccharides.

### 6.2 Proteins

6.2.1 Recall that the amino acids used in protein synthesis are alpha amino acids and are of the L type.

6.2.2 Know the abbreviated names of the twenty amino acids.

6.2.3 Group the amino acids under acidic, basic and neutral amino acids.

6.2.4 Name the amino acids that have a polar R group and those that have an apolar R group.

6.2.5 Write the structural formulae of Ala, Asp, Phe and Glu.

6.2.6 State structural relationship between the following pairs of amino acids. Glu-Gln, Asp-Asn and Cys-Cystine.

6.2.7 Recall that amino acids can donate or accept H+ when the pH of the

medium is altered.

6.2.8 State the amino acids carrying a net positive charge or a net negative charge at the physiological pH.

6.2.9 State two methods and the principles involved, used in the separation of amino acids.

6.2.10 Recall the structural hierarchy of proteins.

6.2.11 Describe how the following may influence the protein structure when present in the protein molecule - Cys, Phe, Tyr, Pro, Lys, Gly, Asp, Glu, His, Ser and Thr.

6.2.12 Explain how the peptide bonds, hydrogen bonds, salt bridges, van der Waals forces and hydrophobic interactions enable the proteins to maintain their structure.

6.2.13 Illustrate the special structural features of myoglobin, haemoglobin, collagen and IgG.

6.2.14 State the non protein moieties in complex proteins.

6.2.15 Explain denaturation, salting out and precipitation of proteins and state the agents that cause it.

6.2.16 Explain the term 'isoelectric point of a protein' and recall how this property is used in protein separation

6.2.17 Describe how proteins act as buffers.

6.2.18 Recall the different functions that are performed by body proteins.

6.2.19 Describe the principles used in the estimation of proteins.

## 6.3 Lipids

6.3.1 Recognise the following structures:
Saturated fatty acids (acetic, propionic, butyric, lauric, myristic, palmitic and stearic), unsaturated fatty acids (oleic, linoleic, linolenic and arachidonic), mono-, di- and triacyl glyceride, phospholipid, cholesterol and their esters.

6.3.2 Know the systematic nomenclature used for naming fatty acids.

6.3.3 Know the significance of the iodine value of a fat.

6.3.4 Explain the known cellular functions of the different fatty acids and their locations.

6.3.5 Explain saponification, rancidity and emulsification of fat.

6.3.6 Explain the structure and function of a phospholipid.

6.3.7 Know the structure and functions of cholesterol and a few of its derivatives.

6.3.8 Draw and label a micelle.

## 6.4 Nucleic Acids

6.4.1 Recall the different nucleic acids in cells and their structural and functional differences.

6.4.2 Recall the type of nucleic acids present in polio, hepatitis B, rabies, measles, influenza and HIV viruses, and their replication.

6.4.3 Know that DNA in the chromosomes is double stranded and that only one of the strands is used at a given time for gene expression.

6.4.4 Know that only 5% of chromosomal DNA is used at a given time and the possible function of the rest.

6.4.5 Know that removal of histone proteins bound to chromosome may result in the expression of new genes.
6.4.6 Recall that lysergic acid may cause chromosomal aberrations and hence the necessity to keep away from drugs.
6.4.7 Giving examples explain the use of synthetic nucleotide analogues used against viral infections.

## 7. Enzymes

7.1 Recall the characteristics of enzymes.
7.2 Explain the terms, holo-enzyme, apo-enzyme, co-enzyme and prosthetic group.
7.3 Explain with the aid of a diagram what is meant by the pH optimum & temperature optimum.
7.4 Define 'unit of enzyme activity'.
7.5 Explain the term initial velocity.
7.6 Explain the principles involved in measuring the activity of an enzyme.
7.7 State the relationship between the rate of a reaction and the concentration of enzyme & substrate.
7.8 Explain the terms, active site and allosteric site.
7.9 Define Km and relate it to the affinity of substrate to the enzyme.
7.10 Know the use of competitive inhibitors in clinical medicine.
7.11 Explain 'competitive' and 'non-competitive' inhibition, giving examples of each.
7.12 Explain 'allosteric effect'.
7.13 Explain the term 'isoenzyme' and their likely use in clinical diagnosis.

## 8. Reactions Which Supply Energy

### 8.1 Biochemical Energy

8.1.1 Recall that ATP is the unit of currency used in energy transactions.
8.1.2 Know that creatine phosphate is a stored form of readily available high energy in the muscle.
8.1.3 Recall that every molecule has a certain amount of energy which may be redistributed within the molecule.
8.1.4 Know that internal energy of a molecule is zero at -2730C.
8.1.5 Recall that the energy released from a molecule may be used for the synthesis of new compounds and performance of work.
8.1.6 Recall that the favoured direction of a reaction is to move from a high energy state to a low energy state, from low entropy to high entropy.
8.1.7 Explain 'exergonic' and 'endergonic' reactions.
8.1.8 Recall that energy trapped in the form of ATP is only 40% of the total energy produced in the body.

### 8.2 Glycolysis

8.2.1 Explain glycolysis and its rate limiting step.
8.2.2 Write the sequence of reactions involved in glycolysis, indicating where energy is used and released and the sites of substrate level

phosphorylation of ADP.

8.2.3 Outline the sequence of reactions by which fructose and galactose enter this pathway.

8.2.4 Know that NADH/NAD ratio controls the glycolytic pathway.

8.2.5 State the final products of glycolysis under anaerobic condition. Outline the fate of these products when oxygen is available.

8.2.6 Explain 'Pasteur effect' and 'Oxygen debt'.

8.2.7 Explain how glycolysis is inhibited by excess ethanol.

8.2.8 Know the reason for the addition of NaF to blood, when estimating blood glucose.

## 8.3 Hexose Monophosphate Pathway (HMP shunt)

8.3.1 Recall that it is the only pathway for the synthesis of ribose and a pathway for the synthesis of NADPH.

8.2 Describe the importance of this pathway in the adipocyte, erythrocyte adrenal cortex and the thyroid gland.

8.3.3 State the functions of glucose phosphate dehydrogenase, transketolase and transaldolase.

8.3.4 Recall that G-6-PD deficiency is the commonest inherited disorder and leads to haemolysis following the administration of certain medications.

83.5 Explain why this pathway is referred to as a shunt.

## 8.4 Tricarboxylic Acid Cycle

8.5.1 With the help of a schematic diagram indicate the sequence, the intermediates, enzymes and coenzymes of the Tricarboxylic acid cycle.

8.5.2 Recall that 5 pairs of H atoms are donated to the respiratory chain and 2 molecules of $CO_2$ are formed per molecule of Acetyl CoA entering the cycle.

8.5.3 Recall that of the 5 pairs of H atoms, one pair is donated to FAD of the respiratory chain and the rest to NAD.

8.5.4 Recall that carbohydrates, proteins and fats are finally oxidized to $CO_2$ and $H_2O$ through the Tricarboxylic acid cycle.

8.5.5 Recall the points of entry of fatty acids, glycerol and amino acids into the Tricarboxylic acid cycle.

8.5.6 Recall that the intermediates of TCA cycle are used in the synthesis of glucose, amino acids and fatty acids.

8.5.7 Know that glucose provides oxaloacetate to oxidize acetyl CoA, derived mainly from fatty acids and that deficiency may lead to ketosis.

## 8.5 Biological Oxidation

8.4.1 List the components of the electron transport chain in the order in which electrons flow from the substrate oxidized to oxygen.

8.4.2 Indicate the sites of entry of H atoms and electrons into this chain.

8.4.3 Indicate the steps at which energy is trapped during this chain.

8.4.4 Explain why ATP is not synthesised at all steps in the chain.

8.4.5 Explain how these processes are regulated by the relative concentration of cofactors and phosphate ions.
8.4.6 List the compounds other than ATP, capable of storing energy in a readily available form.
8.4.7 State examples of reactions in which NAD, NADP, FMN and FAD are used as coenzymes.
8.4.8 Know the action of cyanide, carbon monoxide and phenobarbitone on the respiratory chains and the methods of overcoming it.

### 8.6 Oxidation of Fats

8.6.1 Describe fat hydrolysis in the blood and the adipocyte.
8.6.2 Know the transportation of fatty acids into mitochondria.
8.6.3 List in sequence reactions with enzymes and co-enzymes, involved in the formation of acetyl CoA from fatty acid.
8.6.4 Describe the differences in fat oxidation in brown and white adipocytes.
8.6.5 Explain how glycerol enters the glycolytic pathway.

### 8.7 Oxidation of Ketone Bodies

8.7.1 Name the ketone bodies and state the sites of synthesis.
13.7.2 Explain the pathways by which ketone bodies are oxidized to produce energy.
8.7.3 Recall the ways in which the ketone bodies are excreted from the body when in excess.
8.7.4 Recall the tissues that use ketone bodies as a source of energy.
8.7.5 Know that ketone bodies are rapidly oxidized, unlike glucose.
8.7.6 Recall the effect of increased concentration of ketone bodies at the cellular level and in the whole organism.
8.7.7 Recall two laboratory tests for ketone bodies.

### 8.8 Oxidation of Amino Acids

8.8.1 Recall that transamination and oxidative deamination are methods for the removal of amino groups before oxidising the carbon skeletons.
8.8.2 Recall the amino acids that are classified as glycogenic, ketogenic and both glycogenic and ketogenic.
8.8.3 State the points of entry of carbon skeletons of amino acids into the tricarboxylic acid cycle, giving suitable examples.
8.8.4 Know that ALA, ASP and GLU are the major amino acids in the fasting blood and they carry -NH2 groups to the liver for disposal as urea.
8.8.5 Know that catabolism of amino acids is increased under wasting conditions.

## 9. Synthetic Reactions

### 9.1 Synthesis of Glucose

9.1.1 Explain the term 'gluconeogenesis' and state the precursors used and the cells that provide them.
9.1.2 Recall the tissues and the subcellular sites at which gluconeogenesis takes place and the need for such synthesis.
9.1.3 Outline the steps involved in gluconeogenesis and know the steps that regulate it.
9.1.4 Explain how glycolysis differs from gluconeogenesis.
9.1.5 Recall that cortisol enhances gluconeogenesis and insulin inhibits it.

## 9.2 Synthesis of Glycogen

9.2.1 Explain the term 'glycogenesis'.
9.2.2 Recall the cells in which it takes place.
9.2.3 Outline the reactions involved in the synthesis of glycogen, explaining the rate controlling step.
9.2.4 Know the functions of hepatic glycogen and muscle glycogen.
9.2.5 Know the existence of glycogen storage diseases and the metabolic derangements resulting from them.

## 9.3 Synthesis of Lactose

9.3.1 State the steps involved in the synthesis of lactose starting from glucose.
9.3.2 Explain why lactose is synthesized in the lactating mammary cell only.
9.3.3 Describe the structure of lactose synthetase and the function of each of the subunits it is composed of.

## 9.4. Synthesis of Fatty acids and Triacyglycerides

9.4.1 Outline the synthesis of palmitic acid starting from acetyl CoA, mentioning the enzymes and co enzymes involved.
9.4.2 State the rate limiting step in the denovo synthesis of fatty acids and the factors that regulate it.
9.4.3 Recall that NADPH used in fatty acid synthesis is derived chiefly from the HMP shunt that is adjacent to it.
9.4.4 State how palmitic acid is likely to be converted to (a) stearic (b) lauric (c) oleic acid.
9.4.5 State the site of (a) fatty acid synthesis (b) chain elongation (c) chain shortening (d) unsaturation of fatty acids in the cell.
9.4.6 State the precursors and the pathway involved in the synthesis of glyceryl phosphate.
9.4.7 State how glyceryl phosphate is converted to triacyl glycerol.
9.4.8 Outline the reaction involved in the synthesis of the phosphatidyl choline.
9.4.9 State the precursors of triglyceride synthesis in the (a) intestinal mucosal cell (b) adipocyte (c) hepatocyte (d) mammary gland
9.4.10 Know that fat stored in the upper part of the body is different from those in the lower part, both in storage size and mobility.

### 9.5 Synthesis of Cholesterol

9.5.1 Recognize the structure of cholesterol.
9.5.2 Recall the rate limiting step and factors that effect cholesterol synthesis.
9.5.3 Recall the functions of cholesterol and its derivatives
9.5.4 State the tissues in which the majority of the cholesterol is synthesized.

### 9.6 Synthesis of Purines

9.6.1 Recognize the structures of adenine and guanine.
9.6.2 State the precursors of purines.
9.6.3 State the importance of folic acid in the synthesis of purines.
9.6.4 State the rate limiting step and the factors that influence it.
9.6.5 Recall that inosinic acid (IMP) is the first purine synthesised.
9.6.6 Outline the steps in the conversion of IMP to AMP.
9.6.7 State how the concentration of ATP and GTP affect their synthesis.
9.6.8 Explain how azaserine and the antibacterial agent, sulphonamide, affect purine synthesis.

### 9.7 Synthesis of Pyrimidines

9.7.1 Recognize the structure of uracil, cytosine and thymine.
9.7.2 State the precursors of pyrimidines and the site of synthesis.
9.7.3 State the reactions involved in the synthesis of carbamoyl aspartate mentioning the enzymes and co enzymes.
9.7.4 Mention the intermediates in the convention of carbamoyl aspartate to UMP.
9.7.5 Mentioned the rate limiting step and the factors that effect the synthesis of UTP.
9.7.6 Recall that it is UTP that is aminated to produce CTP.

## 10. Excretion of Metabolites

### 10.1 Cell Waste

10.1.1 Know the end products of carbohydrate, protein, lipid and nucleic acid catabolism.
10.1.2 Know that ammonia is toxic and that it needs to be removed as urea.
10.1.3 Know the routes of waste excretion in the body and the waste products that are removed through each route.
10.1.4 Recall that the cell is in a state of flux and that anabolism and catabolism of biomolecules is determined by the concentration of the pools within the cell and the hormones that interact with them.
10.1.5 Know that most nutrients in excess of their requirements are excreted as cell waste and that energy is an exception.
10.1.6 Know that impaired excretion of cell waste leads to toxicity.
10.1.7 Know that cancer leads to increased cell waste arising from lack of regulation of metabolic pools in the cell.
10.1.8 State the criteria that enable you to distinguish between a non-excretable product and an excretable product.

## 10.2 Amino nitrogen Excretion

10.2.1 Design an experiment to show that N derived from protein forms a major fraction of total N excreted in the urine.
10.5.2. Explain what is meant by the 'amino acid pool' and 'turnover' of proteins.
10.2.3 Recall that the 'turnover rate' of proteins differs from cell to cell.
10.2.4 Recall that alpha
amino N excretion varies with the pool size.
10.2.5 Using schematic diagrams explain what is meant by 'transamination'.
10.2.6 State the function of transaminases and the importance of transamination to the cell.
10.2.7 State the significant of the fact that the equilibrium constant for transamination is approximately one.
10.2.8 State the co-enzyme used in transamination indicating the different form in which it exist.
10.2.9 Giving the chemical names of substrates and products illustrate the reaction catalysed by aspartate amino transferase (ASP) and alanine amino transferase (ALT)
10.2.10 Explain the term 'deamination' and 'oxidative' determination.
10.2.11 Describe the importance of glutamic dehydrogenase to the cell.
10.2.12 Write the individual reactions of the Krebs-Henseleit urea cycle, explaining the necessity for this cycle to operate.

10.2.13 Design a simple experiment to demonstrate the chemical activity of alanine amino transferase.
10.2.14 State the rate limiting step in urea synthesis.
10.2.15 Design an experiment to identify the intracellular site of urea synthesis.
10.2.16 Know the urea N excretion of a person on zero N balance, negative nitrogen balance, positive N balance and a non protein diet.

## 10.3 Products of Nucleic Acid Catabolism

10.3.1 Recall that hypoxanthine and xanthine are intermediates in the catabolism of adenosine and guanosine respectively.
10.3.2 Describe the conversion of hypoxanthine to uric acid.
10.3.3 Explain with reference to xanthine oxidase, how a deficiency of molybdenum can affect uric acid formation.
10.3.4 Explain how allopurinol affects the conversion of hypoxanthine to uric acid.
10.3.5 Recall the solubility of uric acid at acid and alkaline pH.

## 10.4 Excretion of Creatine Metabolites

15.4.1 Outline the synthesis of creatine phosphate from its precursors.
15.4.2 Recall the function of creatine phosphate.
15.4.3 State why creatinine excretion is obligatory.
15.4.4 Recognize the chemical structure of (a) creatinine (b) creatinine phosphate.
15.4.5 Recall that picric acid is used for the estimation of creatinine.

15.4.6 Recall that daily output of urinary creatinine is an indirect measure of muscle mass.

### 10.5 Excretion of Sulphur and Phosphorous Metabolites

10.5.1 Know that dietary protein is the major source of sulphur and phosphorous excreted and that S and P are oxidized to sulphate and phosphate.
10.5.2 Recall that these give rise to acidic urine.
10.5.3 Recall that sulphur can be excreted as ethereal sulphate and other organic sulphate during detoxication.

## 11 Metabolic Regulation

### 11.1 General

11.1.1 Explain the need for control of cellular activity.
11.1.2 List the different mechanisms by which cellular activity is controlled.
11.1.3 Recall that all such mechanisms are directed towards regulation of careful use of nutrients without wastage.

### 11.2 Control of Enzyme Synthesis

11.2.1 Outline the steps involved in protein synthesis.
11.2.2 Explain the functions of the promoter, operator and regulator genes.
11.2.3 Illustrate 'induction' and 'repression' of protein synthesis giving one example of each.

### 11.3 Regulation of Enzyme Activity

11.3.1 Illustrate the different ways in which activity of existing enzymes could be regulated, citing examples.
11.3.2 Recall that most regulatory enzymes are allosteric in nature.
11.3.3 Recall how allosteric modulators regulate enzyme activity.
11.3.4 Describe the regulatory functions of the following; hexokinase, glucose phosphatase, phosphofructokinase, fructose diphosphatase, pyruvate dehydrogenase, pyruvate carboxylase, citrate synthase and isocitrate dehydrogenase, acetyl CoA carboxylase, HMG CoA reductase, aspartate carbamoyl transferase and phosphoribosyl pyrophosphate amino transferase.
11.3.5 Explain how the activity of an enzyme could be regulated by covalent changes in its molecule.
11.3.6 Explain how cyclic AMP affects the activity of the following: Glycogen synthesis, phosphorylase, adipocytic triglyceride lipase and pyruvate dehydrogenase.

### 11.4 Hormonal Control

11.4.1 Explain what hormones are, and state how they differ from enzymes.
11.4.2 State the main structural features of adrenaline, thyroxine,

prostaglandins, insulin, corticosteroids and 1,25 dihydroxy cholecalciferol.

11.4.3 State how steroid and thyroid hormones differ from other hormones in their sites and mechanism of action in the cell.

11.4.4 List the hormones that increase, decrease, cyclic AMP levels in cells.

11.4.5 State the different biochemical actions of insulin, somatotropin, corticosteroids and glucagon on adipocyte, muscle cell and nerve cell.

11.4.6 Explain the action of steroid and thyroid hormones on nuclear chromosomes.

## 12. Cell Signaling

12.1 Explain the term 'signal transduction'.

12.2 Understand the need for communication among diverse cells of a eukaryote.

12.3 Recall that polypeptide hormones, steroid and thyroid hormones, nitric oxide and neurotransmitters are used as signals.

12.4 Know the roles of cyclic AMP, cyclic GMP, phosphoinositol and calcium ions as second messengers.

12.5 Outline the step involved in the synthesis of cyclic AMP.

12.6 List the factors that increase, decrease, cyclic AMP concentration in a cell.

12.7 State the action of prostaglandins on the level of cyclic AMP in adipocytes and in cells of the adrenal and testis.

12.8 Know the signal, its receptor, propagation and the final response in the signal pathway used by epinephrine, insulin, cortisol and nitric oxide.

12.9 Know that transformation of normal to cancer cells may have resulted from loss of contact cell inhibition and modified protein kinase activity.

## 13 Biochemistry of the Gene

13.1 Recall the contributions of Mendel,Avery,MacLeod & MacCarty, Watson & Crick, Jacob & Monod, Kornberg & Khorana in the development of the gene concept.

13.2 Define the terms 'gene' and 'gene expression'.

13.3 Know that gene is the basic information unit in biology and its expression in space and time resulted in diversity and evolution.

13.4 Describe the elements located in front of the gene that control transcription.

13.5 Know the arrangement of genes in prokaryote and eukaryotes.

13.6 Understand gene activation.

13.7 Explain mutation on the basis of chemical change in DNA.

13.8 Know that genes are in pairs (autosomes) and that a defect in one is not life threatening.

13.9 Recall the natural mechanisms available for the protection of DNA and clinical cases where such protection is not available.

13.10 The principles involved in genetic engineering.

13.11 Understand 'cloning' and its applications.

13.12 Understand the applications of gene therapy.

## 14. Genetic Changes

### 14.1 Gene Transfer

14.1.1 Recall that it is a method of transfer of genes from one organism to another.
14.1.2 List the steps involved in the insertion of foreign genes into a host genome.
14.1.3 Recall that growth hormone, interferon and insulin are a few of the human proteins cloned in *E.coli*.
14.1.4 State the potential clinical applications of genetic engineering.
14.1.5 Know the difference in gene expression in prokaryote and eukaryotes.
14.1.6 Recall that gene therapy has been successful in a few cases and that adenosine deaminase was one such case.
14.1.7 Describe the application of the Northern, Southern and Western blot techniques.
14.1.8 Explain the PCR technique and its use.

### 14.2 Mutations

14.2.1 Explain mutation on the basis of chemical change in DNA.
14.2.2 Recall that not all mutations give rise to defective proteins.
14.2.3 Explain 'point mutation' using HbS as an example.
14.2.4 Explain deletion, insertion, transition and transvertion.
14.2.5 List the common causes of mutation.
14.2.6 List some applications of mutation.
14.2.7 Taking HbS as an example, explain how HbA has been transformed into HbS.

## 15 Gene Expression and Regulation

### 15.1 Gene Expression

15.1.1 Explain with diagrams, transcription of a genetic message.
15.1.2 Describe the processing of RNA molecules that lead to functional mRNA.
15.1.3 Explain the catalytic functions of small nuclear RNA.
15.1.4 Describe the steps involved in protein synthesis.
15.1.5 State the different post-translational modifications of proteins and explain the sites and mechanisms which bring about these changes in the nascent protein molecules..
15.1.6 Explain the genetic code and the 'wobble hypothesis'.
15.1.7 Explain the biochemical basis for the differences in action of Penicillin, Sulphonamides, Streptomycin, Neomycin, chloramphenicol, Tetracycline, Rifampicin and Nalidixic acid.
15.1.8 Explain the genetic basis of Sickle Cell Disease, Sickle Cell Anaemia and Thalassaemia ($\alpha$ and $\beta$ types).

### 15.2 Gene Regulation

15.2.1 Recall that the major form of gene regulation is at the transcription level.
15.2.2 Describe the lactose operon and its operation in bacteria.

15.2.3 Recall that regulated expression of genes is required for development, differentiation, and adaptation and explain how these are brought about.

15.2.4 Describe the tissue specific expression of lactate dehydrogenase (LDH) and creatine phosphokinase (CPK)

15.2.5 Describe the action of 1, 25 dihydroxy cholecalciferol on calcium binding protein.

## 16 Cell Cycle and the Cancer Cell

16.1 Describe the different phases of the mammalian cell cycle.

16.2 List the principle macromolecules synthesised during the different phases of the cell cycle.

16.3 Recall that cytoplasmic proteins and organelles are synthesised continuously throughout the G1, S and G2 phases.

16.4 Recall that during mitosis, (a) synthesis of DNA and RNA is turned off (b) protein synthesis is greatly reduced.

16.5 Recall the action of the following on cell division: hydroxyurea, actinomycin D, puromycin, colchicine and dTTP.

16.6 Explain how the cell cycle is affected by an
(a) excess of nutrients.
(b) inadequacy of nutrients.

16.7 List the factors that could cause transformation of normal cells into cancer cells.

16.8 State how normal cells differ from cancer cells in,
(a) energy metabolism.
(b) DNA synthesis.
(c) cell division.

16.9 Explain the use of aminopterin and amithopterin in the treatment of cancer.

16.10 State why the $G_2$ phase of the cell cycle is the one most affected by ionizing radiation.

16.11 Recall the effect of synthetic nucleotide analogues on DNA synthesis.

16.12 Recall the use of anti-viral agents against HIV, chickenpox etc.

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