

## CHAPTER OBJECTIVES

### **Topic 1: Introduction**

1. Know the biochemical language and terminology.
2. Realize how "energy" is the central theme in biochemistry.

### **Topic 2: Cell Structure and Function**

1. List the features of eukaryotic organisms.
2. Define what constitutes an organelle and specify the functions of the organelles found in the human cell.

### **Topic 3: Biomacromolecules**

1. Organic review of
  - covalent bonds and their relationship to the number of unpaired electrons
  - significance of atomic numbers
  - stereoisomers; chirality
  - electronegativity
  - conformation/configuration
2. Review classes of organic molecules based on functionality i.e., alcohol, aldehyde, ketone, carboxylic acid, forms of the carboxylate ion, primary and secondary amines, ammonium forms.
3. Review terms used to name functional groups as attachments i.e., hydroxyl, sulfhydryl, acyl, acetyl, aryl, carbonyl, amino, ammonium, phosphate, phosphoryl.
4. Review bond types made by condensing 2 functionalities i.e., ester, thio ester, amide, phosphate ester, mixed phosphate anhydride, diphosphate anhydride, disulfide cis/trans double bond, aromatic, glycosidic.
5. Review the following types of reactions: condensation/hydrolysis, redox, hydrogenation/dehydrogenation, substitution, dehydration/hydration.
6. Know the names of the biomacromolecules found in the cell.
7. Know the monomeric units that constitute biomacromolecules listed in objective #6.

#### **Topic 4: Water**

1. Describe the concept of electronegativity and explain its role in determining whether a bond is polar or non-polar.
2. Explain how ion-dipole and dipole-dipole interactions between dissolved ions or molecules in water aid in their solubility.
3. Define the terms hydrophilic and hydrophobic. Discuss how the preferential interactions of molecules with water or with each other determines their solubility or insolubility.
4. Draw the general structure for a micelle and explain the nature of the driving force for micelle formation.
5. Indicate the characteristics a molecule must possess in order to be a hydrogen-bond donor or acceptor.
6. Become familiar with the types of non-covalent bonding forces.
7. State the relationship between the strength of an acid and its  $K_a$ ' and  $pK_a$ ' values.
8. Review the relationship between the pH of a solution and its hydrogen-ion concentration.
9. Make a plot for the titration of a weak acid and indicate the species that are present at the beginning, the half-way point and at the equivalence point in the titration.
10. Define the terms buffer and buffer capacity and explain how the buffering capacity changes as a function of pH.
11. Give some examples of buffers and indicate the buffer species that reacts with any added acid or base.
12. Be able to solve problems using the Henderson-Hasselbach equation.

#### **Topic 5: Amino Acids, Peptides and Proteins**

1. Learn the structure, the names and the 3 letter abbreviation of the 20 amino acids.
2. Indicate the difference between stereoisomers such as the D- and L-isomers of an amino acid.
3. Characterize the amino acids according to whether the side group is aromatic, polar or non-polar, positively or negatively charged, has a chemical functional group and/or can participate in hydrogen bonding interactions.

4. Calculate the pH at which the zwitterion exists in aqueous solution for a non-polar, a basic and an acidic amino acid.
5. Explain the basis of electrophoresis and the 3 types of column chromatography and how each technique can be used to separate a mixture of amino acids.
6. Draw the structure of a tripeptide, indicating the N-terminal and C-terminal residues and the peptide bonds. Also indicate the atoms in the peptide backbone and in the side groups that can participate in a hydrogen bond.
7. Draw the resonance structures for the peptide bond which are consistent with its planarity.
8. Draw the structure for glutathione in the oxidized and reduced forms.
9. How can a titration curve tell you at which pH a molecule will act as an effective buffer? Use this information to interpret the titration curve for glycine.

### **Topic 6: Three Dimensional Structure of Proteins**

1. Draw the structure for a dipeptide and point out the peptide bond, the C-terminal, and the N-terminal residues.
2. Name and describe the four levels of protein structure, indicating the types of forces associated with each level of structure.
3. List the four fundamental bonding interactions found in all proteins.
4. Describe the difference between a structural domain and a subunit.
5. Explain specifically how extreme pH, detergents, heat, high salt concentration, or the addition of a reagent such as urea acts to denature proteins.
6. List the characteristics of an  $\alpha$ -helix and the interactions that stabilize it.
7. Characterize the structure and the bonding in a  $\beta$ -pleated sheet and indicate the difference between a parallel and an anti-parallel  $\beta$ -pleated sheet.

### **Topic 7: Protein Function**

1. Describe the structure of myoglobin and explain the role of the prosthetic group in its function.

2. Discuss the O<sub>2</sub> binding curves for myoglobin and hemoglobin. What do these curves say about the nature of the binding of O<sub>2</sub> in each metalloprotein?
3. Indicate how H<sup>+</sup>, CO<sub>2</sub>, and 2,3-bisphosphoglycerate influence the binding of O<sub>2</sub> in hemoglobin.

### **Topic 8: Enzymes**

1. Describe the nature of the active site in an enzyme.
2. Outline the features of enzymes that display a hyperbolic or sigmoidal reaction profile.
3. Describe the Michaelis-Menten kinetics model. Define all terms.
4. Discuss the significance of K<sub>M</sub> and V<sub>max</sub> values for an enzyme.
5. Describe the enzyme interactions involved with competitive and non-competitive inhibitors.
6. Indicate the characteristics of the Lineweaver-Burke plots as a result of a competitive or non-competitive inhibitor interacting with an enzyme.
7. State the definition of a zymogen and give an example of one.
8. State the definition of an isoenzyme and give an example of one.
9. Contrast the kinetics of allosteric enzymes with simple Michaelis-Menten kinetics. Note the similarities to the oxygen binding curves of hemoglobin and myoglobin.
10. Know the classes of enzymes and representative examples for each.

### **Topic 9: Coenzymes**

1. Name the characteristics of a coenzyme and describe how coenzymes participate in catalysis. List the water soluble vitamins that are the components of CoE.
2. Recognize the structures of NAD, FAD. Explain their reduction process and their roles in metabolism.
3. Contrast the metabolic roles of NADH and NADPH.
4. Be able to identify the vitamin and its active coenzyme form. Be able to state common features among the coenzymes.

## **Topic 10: Bioenergetics and Metabolism**

1. Distinguish between an exergonic and an endergonic process.
2. Discuss the relationship between catabolic and anabolic processes in cellular metabolism.
3. Provide a number of equivalent definitions for both oxidation and reduction.
4. Make a list of the most important biological electron acceptors. Indicate the part of the molecule that is altered by the reduction.
5. List the most important biological electron donors; indicate the part of the molecule that is altered as a result of oxidation.
6. Explain the meaning of the term “high energy” bond.
7. Draw the structure for ATP. Point out the acid anhydride and the ester linkages and indicate the high energy bonds.
8. Indicate the number of electrons and protons that NADH, NADPH and FADH<sub>2</sub> transfer when they are oxidized.
9. Draw the structure for coenzyme A (CoA). Point out the recognizable components in its chemical structure and indicate the role of CoA in metabolism.
10. List the three metabolic fates of glucose and indicate whether they are anaerobic or aerobic.

## **Topic 11: Electron Transport and Oxidative Phosphorylation**

11. Indicate the cellular location where glycolysis, the citric acid cycle, electron transport and oxidative phosphorylation take place.
12. Specify the role of FADH<sub>2</sub>, NADH, and O<sub>2</sub> in the electron transport chain.
13. Name the three complexes, the cytochromes, and the accessory molecules in each complex and the order in which the complexes are found in the electron transport chain.
14. Indicate the electron carriers that serve to transfer electrons between the complexes in the electron transport chain.
15. Identify the location of ATP synthase in the cell and its role in oxidative phosphorylation.
16. Define the terms uncouplers and respiration inhibitors, and indicate the general mechanism by which each operates.

17. Discuss the basic tenets of the chemiosmotic hypothesis, which proposes a mechanism for the coupling of electron transport to oxidative phosphorylation.
18. Describe the two shuttle mechanisms by which electrons from NADH are transported from the cytoplasm into the mitochondria.
19. Review the cytoplasmic and mitochondrial reactions involved in the complete oxidation of glucose and indicate the reactions that result in the production of ATP, NADH, and FADH<sub>2</sub>.

### **Topic 12: Carbohydrates**

1. Be prepared to recognize stereoisomers and distinguish between enantiomers and diastereomers, including epimers and anomers.
2. Outline the characteristics of a hemiacetal, an acetal, a hemiketal, and a ketal.
3. Draw the Fischer projection formulas for aldoses and ketoses and classify the molecules according to the type of stereoisomer.
4. Convert Fischer projection formulas for aldohexoses into the corresponding Haworth formulas.
5. Point out in both the Fischer and Haworth formulas the carbon atom that defines the D- or the L-family of stereoisomers.
6. Indicate the chemical basis for a mono- or disaccharide being a reducing or nonreducing sugar.
7. Write the equations for monosaccharides undergoing (1) reduction, (2) oxidation, (3) esterification, and (4) glycoside formation.
8. Draw the structures for the reactants and products in the formation of sucrose, lactose, and maltose. Point out the anomeric carbon atoms and the type of linkages formed in the products.
9. Catalog the similarities and differences in the composition, structure, and function of the major polysaccharides found in plants and animals.
10. Draw and name two of the major amino sugars and indicate in which polysaccharide they are found.

### **Topic 13: Glycolysis**

1. State the primary function of the glycolytic pathway.
2. Outline the steps involved in the conversion of glucose to pyruvate.
3. Name the types of reactions involved in glycolysis. Indicate which reaction involves the production of use of ATP.
4. Name the enzyme that catalyzes each reaction in glycolysis and specify the enzymes that take part in the regulation of glycolysis.
5. Indicate the allosteric effector(s) for each regulatory enzyme and the effect that is produced by the interaction.
6. Specify the difference between substrate-level phosphorylation and oxidative phosphorylation involved in ATP production.
7. Specify the alternate metabolic fates of pyruvate and indicate the conditions under which they occur.
8. Indicate the extent to which the energy released by the oxidation of glucose in glycolysis is “captured”. Into what molecular form is this energy captured?
9. Define the term isoenzyme; give a real example; and indicate how an isoenzyme discussed in this topic is used in the diagnosis of a myocardial infarction.
10. Discuss how  $\text{NAD}^+$  is regenerated in anaerobic glycolysis and why this is so important to the cell under anaerobic conditions.
11. Compare the common and the unique features in the reductive pathways in which pyruvate is converted to lactate or ethanol.

### **Topic 14: Additional Pathways in Carbohydrate Metabolism**

1. State the functional role of gluconeogenesis.
2. Write down the three reactions and their associated regulatory enzymes in the gluconeogenesis pathway that are different than those in glycolysis.
3. Specify the biological roles of the pentose phosphate shunt (HMP).
4. List the types of reactions in the oxidative phase. How is HMP linked to EMP?
5. Characterize the structure and function of the polysaccharide, glycogen, and contrast these characteristics with that of starch and amylopectin.

6. Outline the individual steps involved in the conversion of glycogen to glucose.
7. Outline the reactions involved in the formation of glycogen from glucose, indicating the role of UTP and glycogenin.
8. Discuss the major enzymes involved in glycogen synthesis and glycogen breakdown and indicate how regulation is achieved. (short and long term)
9. Discuss the characteristics and the role of phosphofructokinase-2 and fructose biphosphatase-2 in carbohydrate metabolism.
10. Under anaerobic conditions, due to oxygen debt in skeletal muscles, discuss the interrelationship between liver and muscle cells and the metabolic interconversions of glucose, lactate, and glycogen (Cori cycle).

### **Topic 15: Citric Acid Cycle**

1. List the components of the multienzyme complex, pyruvate dehydrogenase. How is it regulated?
2. For the conversion of pyruvate to acetyl-CoA, write the five stepwise reactions involved and specify the enzymes and the coenzymes associated with each intermediate conversion.
3. State the primary catabolic and anabolic roles of the citric acid cycle and indicate the cellular location of the process.
4. Name and draw the structures of the intermediates for the citric acid cycle.
5. List the enzymes associated with each reaction in the citric acid cycle and indicate the type of reactions that take place.
6. Indicate the regulatory enzymes in the cycle and the effector molecules that act as inhibitors and activators for these allosteric enzymes.

### **Topic 16: Nitrogen Metabolism and Urea Cycle**

1. Name the major organ of amino acid degradation in mammals.
2. Differentiate between oxidative deamination and transamination.
3. Describe the reaction catalyzed by glutamic acid dehydrogenase.
4. Review pyridoxamine phosphate and pyridoxal phosphate. Name the dietary precursor.

5. Describe the transamination reaction and explain the Schiff base mechanism.
6. List the intermediate precursors of the nitrogen and carbon atoms of urea.
7. Name the enzymes and the intermediary metabolites of the urea cycle, note their intracellular locations. Account for the ATP requirements of the cycle.

### **Topic 17: Lipids**

1. State the criterion for a molecule to be classed as a lipid.
2. Write the general equation for the reaction of:
  - a. a carboxylic acid and phosphoric acid
  - b. phosphoric acid and an alcohol
3. Distinguish between a triglyceride, phosphatidic acid, and a phosphoacylglyceride.
4. Point out the linkages found in molecules such as lecithin and cephalin.
5. Draw the structure for the general steroid skeleton and name three important molecules derived from it.
6. List four major physiological functions of fatty acids.
7. Draw the structure of a saturated and an unsaturated fatty acid from its name. Specify the  $\alpha$ ,  $\beta$ ,  $\omega$  carbon atoms and designate the position of the double bond in a fatty acid given either the  $\Delta$  or the  $\omega$  number.
8. Know the names and structures of the saturated and unsaturated fatty acids from  $C_{12}$  to  $C_{20}$ .

### **Topic 18: Lipid Metabolism**

1. Indicate the cellular locations for the initial hydrolysis of a triacylglyceride and phosphatidyl choline,  $\beta$ -oxidation of fatty acids and fatty acid biosynthesis.
2. Outline the steps involved in the  $\beta$ -oxidation of fatty acids, starting with the hydrolysis of a triacylglyceride and including the transport mechanism that acyl groups utilize to enter the mitochondria.
3. Outline the catabolism of odd-chain fatty acids. Note the CoEs involved in the process.
4. Calculate the number of ATP molecules produced in the complete oxidation of a saturated fatty acid.
5. Consider the structures for the ketone bodies, the metabolic conditions in which they are produced and the reactions that describe their formation.

6. Describe the role of acetyl-CoA, malonyl-CoA and the acetyl-CoA carboxylase complex, fatty acid synthetase and acyl carrier protein (ACP) in fatty acid biosynthesis.
7. Summarize the important differences between the anabolic and catabolic pathways for fatty acids.

### **Topic 19: Nucleotides**

1. Describe the nitrogenous bases and sugars found in nucleic acids.
2. Describe the formation of nucleosides and nucleotides.
3. Describe the linking of nucleotides in forming polynucleotides.
4. Describe the base pairing and antiparallel nature of double stranded nucleic acids.