Essay Questions

Possible essay topics for student assessment are given below. They are given under the chapter to which they are most relevant, but many require reading in other chapters as well as indicated in the brackets after each title.

CHAPTER 1: CELLS AND TISSUES

- Why are viruses not regarded as being alive? {Chapter 1}
- A male patient presents as failing to have children with a wife known to be fertile. Discuss the different microscopical techniques that could be used to investigate his spermatozoa. {Chapter 1}

CHAPTER 2: WATER AND MACROMOLECULES

- Nitric, sulphuric and hydrochloric acids are all strong acids. What is meant by this statement? Nitric and sulphuric acids are also oxidizing agents but hydrochloric acid is not. Discuss this difference. {Chapter 2}
- Polysaccharides offer possibilities of enormous structural complexity. How does this arise? Compare and contrast polysaccharides with polynucleotides and polypeptides. {Chapter 2}
- Life, at least in the form found on Earth, could not exist without water. Why is water so important in living systems? {Chapters 1, 2 and 9}

CHAPTER 3: MEMBRANES AND ORGANELLES

- Describe the basic structure of a eukaryote membrane. Compare the processes occurring at the inner mitochondrial membrane and the plasma membrane. {Chapters 2, 3, 12, 14, 15, 16}
- Classical plasma membrane channels (such as potassium channels), the gap junction channel, the nuclear pore, and the plasmodesmata of plant cells are all structures that allow hydrophilic solute to pass or bypass a barrier of one or more membranes. Compare their topology. {Chapters 3, 10, 14 and In Depth 17.1 on page 293}

CHAPTER 4: DNA STRUCTURE AND THE GENETIC CODE

- In figure 4.10 on book page 63 we show a hypothetical base sequence encoding the polypeptide sequence MQWVE and use it to illustrate frameshift, nonsense and missense mutations. Create a completely different example that demonstrates the same three classes of mutation. Furthermore, give two examples of nonsense mutation: one which generates a change to a relatively similar amino acid (one with a similar hydrophobicity and charge, see {link to Chapter 9 / Web text box / When a different amino acid will do: conservative mutations}, and one in which the second base of a codon changes from a purine to a pyrimidine, or visa versa, causing a major change in the side chain type. {Chapter 4}
- If you were designing a DNA-based genetic code from scratch (one that still uses the four bases A, T, C and G and which still specifies 20 amino acids) how might the present code be improved? {Chapters 4, 5, 6, 8}

CHAPTER 5: DNA AS A DATA STORAGE MEDIUM

- Compare DNA synthesis on the leading and lagging strand. {Chapter 5}
- Only about 1.5% of the human genome comprises codons that specify amino acids in proteins. What is the remainder and does any of it have a function? {Chapter 5}

CHAPTER 6: TRANSCRIPTION AND THE CONTROL OF GENE EXPRESSION

- Compare and contrast how lactose and tryptophan regulate gene expression in the bacterium *E. coli*. {Chapter 6}
- Glucocorticoid hormones are among the many regulators of gene expression in humans. Describe the key steps that lead to a change in gene regulation when the hormone enters the cell. {Chapter 6}

CHAPTER 7: RECOMBINANT DNA AND GENETIC ENGINEERING

- A scientist recognizes a DNA sequence in a newly sequenced genome as likely to code for a soluble, secreted protein. Describe the steps they might go through to generate large quantities of the protein from transfected cells in culture. {Chapter 7}
- What are the important properties of a plasmid vector that allow it to be used to express a protein in bacteria? Why might a scientist wish to express a protein? {Chapter 7}

CHAPTER 8: MANUFACTURING PROTEIN

- Compare the mechanisms that place an fmet in the P site as the first step in prokaryotic protein synthesis with the mechanisms that place the second and subsequent amino acids in the A site. What common features or shared strategies can be discerned? {Chapter 8}
- Why do some antibiotics inhibit protein synthesis? {Chapter 8}

CHAPTER 9: PROTEIN STRUCTURE

- An insectivorous plant is found to activate heat production in its trap by post-translational modification of an existing protein. The heat volatilizes chemicals that attract insects. Mutagenesis studies pinpoint the critical region for activation of the enzyme as the sequence HATNMTGGYLE. Consider the sequence and discuss which amino acids might be modified to regulate the protein's activity. {Chapter 9}
- We have stated (book page 152) that the sequence of amino acids in a protein contains all of the information necessary to specify the final structure, and that a completely disordered polypeptide chain will refold into the correct shape if allowed to do so, e.g. if a chaotropic reagent is dialyzed away. Insulin is a small protein that consists of two chains held together by disulphide bonds. It is made by synthesis of a larger, single chain called proinsulin that undergoes post translational modification, including proteolysis, to make the active hormone. If one dissolves insulin in 8 moles liter^{-1} urea plus a reagent to break the disulphide bonds and

then slowly removes urea and reagent the activity does NOT return to a significant extent. Suggest an explanation of this paradox – why is insulin folded correctly the first time it is made, but cannot fold correctly if artificially disordered and then allowed to reform? {Chapter 9}

- Describe the strategies that could be used to design a protein that could exist and maintain a stable three-dimensional structure in a hydrophobic solvent such as octane rather than in water. {Chapter 9}

CHAPTER 10: INTRACELLULAR PROTEIN TRAFFICKING

- Why is fusing vesicles to a membrane or pulling vesicles off a membrane an intrinsically difficult thing to do? How is the cell thought to accomplish these steps? {Chapter 10}
- What happens in a lysosome? Where do its contents come from? {Chapters 3, 10}

CHAPTER 11: HOW PROTEINS WORK

- On book page 114-115 we describe how protein engineering created a modified subtilisin enzyme for use in biological washing powder. The modified enzyme had a different K_M and k_{cat} from the wild type protein. Explain the meaning of the terms K_M and k_{cat}. Sketch (or create in a spreadsheet or other program, using the Michaelis-Menten equation) a graph of v_o against [S] for the wild type and modified enzyme, for assays in which each reaction tube contains 1 µmole of subtilisin. Use numerical labels on the axes. (*For more advanced students, using In Depth 11.3 on page 185:* Sketch the Lineweaver-Burke plots that would result from these assays). {Chapter 11}
- Why is allosteric behavior vitally important to hemoglobin? Why can't myoglobin serve as an oxygen transporter? {Chapter 11}

CHAPTER 12: ENERGY TRADING WITHIN THE CELL

- We have listed NADH as one of the four principle cell energy currencies, but many teachers will think this classification inappropriate. Explain what is meant by the term energy currency, and argue the case that NADH should not be described as an energy currency. {Chapter 12}
- Oligomycin is an antibiotic that blocks ATP synthase. If mitochondria are treated with oligomycin what will happen to their oxygen consumption (assume that they have adequate supplies of ADP, phosphate and acetyl CoA)? Why does this happen? {Chapter 12}

CHAPTER 13: METABOLISM

- Compare and contrast:
  β oxidation and fatty acid synthesis
  glycolysis and gluconeogenesis
  glycogen synthesis and glycogen breakdown
  {Chapter 13}
- During starvation the body must maintain blood glucose levels. How does it manage to do this? {Chapter 13}

CHAPTER 14: IONS AND VOLTAGES

- Distinguish between the terms equilibrium and steady state. Illustrate your answer using (1) the concentration of ATP in the cytosol (2) the concentration gradient of exemplar ions across the plasma membrane. {Chapters 13 and 14}
- Explain the concepts of (membrane-bound) channel and carrier. How can these two be so similar structurally yet so different thermodynamically? {Chapter 14}
- Explain how the properties of the voltage gated sodium channel make possible the generation of the action potential. {Chapter 14}

CHAPTER 15: INTRACELLULAR SIGNALLING

- Sodium ions and calcium ions both experience a large inward electrochemical gradient across the plasma membrane and are both used to transmit messages from one part of a cell to another. Contrast the mechanisms used by cells when signaling using these two ions. {Chapters 14 and 15}
- Describe the signaling pathways activated by metabolites of phosphatidylinositol bisphosphate (PIP_2). {Chapter 15}
- What is an intracellular messenger? Many scientists include inositol trisphosphate (IP_3) as an intracellular messenger. Discuss this question, giving arguments for and against the inclusion of IP_3 in the list of intracellular messengers. {Chapter 15}
- Describe some of the signaling pathways downstream of activated receptor tyrosine kinases. How is it that different receptor tyrosine kinases on the surface of the same cell can have different downstream effects? {Chapter 15}

CHAPTER 16: INTERCELLULAR COMMUNICATION

- Electronic logic circuits include “AND” and “  ”gates. Describe how the nervous system implements these logic elements using synapses.

  (An AND gate generates an output when both of its inputs are active. A  gate generates an input when it’s + input is active and its – input is inactive). {Chapter 16}
- An action potential is initiated at the proximal end of a motoneurone axon. Describe, step by step, how this culminates in the contraction of a skeletal muscle cell. {Chapters 14, 15, 16, 17, but the title could easily be modified to be less comprehensive}
- Compare the mechanisms used by steroid hormones, insulin, and adrenaline to modify the behavior of target cells. {Chapters 6, 15 and 16}

CHAPTER 17: MECHANICAL MOLECULES

- The single celled organism Paramecium swims using its many cilia, while amoeba crawls over the surface of soil particles. Explain how molecular motors operate on other cellular proteins and structures to create both of these types of locomotion. {Chapter 17}
- Compare the roles played by the molecular motors dynein, kinesin and myosin. {Chapter 17}

CHAPTER 18: CELL CYCLE AND THE CONTROL OF CELL NUMBER

- Explain how the processes of mitosis and meiosis operate to ensure that progeny cells end up with, respectively, two and one complete copies of the genome. Explain the process and function of meiotic recombination. {Chapter 18}
- After exposure of a eukaryotic cell to ultraviolet light, damage to the DNA is detected and repair mechanisms upregulated. Describe both the mechanism of this upregulation and the details of DNA repair. {Chapters 5 and 18}

CHAPTER 19: THE CELL BIOLOGY OF THE IMMUNE SYSTEM

- Discuss the internal and external cues that control whether a vertebrate cell initiates apoptosis. {Chapters 18 and 19}
- Complex splicing operations on both DNA and RNA allow generation of the antibodies presented on mature B cell membranes and secreted by plasma cells. Explain these processes, distinguishing clearly between those carried out on DNA and those carried out on RNA. {Chapter 19}
- Explain the function of major histocompatibility complex proteins. {Chapters 10 and 19}

CHAPTER 20: CASE STUDY: CYSTIC FIBROSIS

- How is it that mutations in different parts of a gene may produce the same disease although sometimes with different degrees of severity? {Chapter 20}
- Discuss why gene therapy has so far not lived up to its promise in providing a cure for cystic fibrosis. {Chapter 20}