IB BIOLOGY, Study Guide 1: Cell Theory, Membranes and the Cell Cycle

Chapter 2.1 Cell Theory

Assessment Statements

2.1.1 Outline the cell theory.

- All organisms are composed of living things
- Cells are the smallest units of life
- All cells come from pre-existing cells

2.1.2 Discuss the evidence for the cell theory.

Several scientists including Robert Hooke, Antonie van Leeuwenhoek and Mathias Schleiden were among the first to observe living cells as “independent, separate beings”. Louis Pasteur showed that living organisms cannot “spontaneously” appear, and to this day, no living organism has been identified that is not made up of at least one cell.

2.1.3 Statement. **Unicellular organisms are capable of carrying out all functions of life.** These functions include: metabolism, growth, reproduction, response, homeostasis and nutrition.

2.1.4 Compare the relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using the appropriate SI unit.

Most **cells** are up to 100 micrometers; **organelles** are up to 10 micrometers. **Bacteria** are up to 1 micrometer and **viruses** are up to 100 nanometers. **Membranes** are approximately 10 nanometers thick and **molecules** are close to 1 nanometer.

2.1.6 Explain the importance of the surface area to volume ratio as a factor limiting cell size.

The surface of the cell, the membrane, controls what materials move in and out of the cell. As an organism grows larger, the surface area increases but at a much slower rate than the volume. This means that a large cell has less surface area than a smaller one. Because of this cells are limited to the size they can attain and still be able to carry out the functions of life.

2.1.7 Statement. **Multicellular organisms show emergent properties.** We start out as a single cell that has the ability to reproduce very rapidly, and the resulting cells go through a differentiation process to produce all the required cell types that are necessary in the functioning organism.

2.1.8 Explain that cells in multicellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others.

Differentiation leads to several different cell types being produced from one original cell. This process is the result of the expression of certain specific genes but not others. Genes, segments of DNA on a chromosome, allow for the production of all the different cells of an organism. Therefore each cell contains all the genetic information for the production of the complete organism.
2.1.9 **Statement.** Stem cells retain the capacity to divide and have the ability to differentiate along different pathways. These stem cells retain the ability to form any type of cell in an organism and can form even a complete organism. When stem cells divide to form a specific type of tissue, they also produce some cells that remain as stem cells. This allows for continual production of a particular type of tissue.

2.1.10 **Outline one therapeutic use of stem cells.**

- Parkinson’s disease and Alzheimer’s disease are caused by loss of brain cells, it is hoped that implanted stem cells could replace many of these lost cells and relieve disease symptoms
- Certain forms of diabetes deplete the pancreas of essential cells and it is hoped that a stem cell implant could have positive effects
- Blood stem cells have been routinely introduced into humans to replace the damaged bone marrow of some leukemia patients

**Chapter 2.2 Prokaryotic cells**

*Assessment Statements*

2.2.1 **Draw and label a diagram of the ultrastructure of *E. coli* as an example of a prokaryote.**

2.2.2 **Annotate the diagram with the functions of each named structure.**

**Prokaryotic Cell**

1. **Cell Wall:** protects cell and maintains cell shape
2. **Capsule:** allows bacteria to adhere to structures (i.e. skin, teeth)
3. **Plasma membrane:** controls movement in and out of the cell
4. **Nucleoid region:** non-compartmentalized single, continuous, circular thread of DNA
5. **Ribosomes:** sites of protein synthesis
6. **Pilus:** allow bacteria to adhere to one another in preparation for the transfer of DNA (sexual reproduction)
7. **Flagellum:** allow cell movement

2.2.4 **Statement.** Prokaryotic cells divide by binary fission. During this process the DNA is copied, the two daughter chromosomes become attached to different regions of the plasma membrane, and the cell divides into two genetically identical daughter cells.
Chapter 2.3 Eukaryotic cells

Assessment Statements

2.3.1 Draw and label a diagram of the ultrastructure of a liver cell as an example of an animal cell.

2.3.2 Annotate the diagram with the functions of each named structure.

2.3.4 Compare prokaryotic and eukaryotic cells using annotated diagrams.

**Eukaryotic Cell**

- **Ribosome**: sites of protein synthesis; free in the cytoplasm or attached to the ER
- **Rough ER**: a site of protein synthesis
- **Plasma membrane**: controls movement in and out of the cell
- **Nucleus**: isolated region where the cells’ DNA resides
- **Nucleolus**: dense, solid structure involved in ribosome synthesis
- **Nuclear pore**: allows communication between the nucleus and the cytoplasm
- **Golgi complex (apparatus)**: stores, modifies and packages proteins
- **Centriole**: composed of microtubules; make up the centrosome
- **Smooth ER**: ER without ribosomes
- **Lysosomes**: contain transport enzymes
- **Mitochondria**: carry out respiration

2.3.5 State three differences between plant and animal cells.

**Plant Cells**

- Chloroplasts are present in the cytoplasm
- Stores carbohydrates as starch
- Rigid cell wall maintains a fixed, angular shape

**Animal Cells**

- There are no chloroplasts
- Stores carbohydrates as glycogen
- Without a cell wall cell is flexible and more rounded in shape

2.3.6 Outline two roles of extracellular components.

The extracellular matrix (ECM) forms fiber-like structures that anchor the matrix to the plasma membrane. This strengthens the plasma membrane and allows attachment to other cells. The ECM allows cell-to-cell interaction, possibly altering gene expression and coordinating cell action within a tissue.
Chapter 2.4 Membranes

Assessment Statements

2.4.1 Draw and label a diagram to show the structure of a membrane.

![Plasma membrane diagram]

2.4.2 Explain how the hydrophobic and hydrophilic properties of phospholipids help to maintain the structure of cell membranes.

Membranes have two distinct areas when it comes to polarity and water solubility. One area is water soluble and polar, and is referred to as hydrophilic (water-loving). The other area is not water soluble and is non-polar. It is referred to as hydrophobic (water-fearing). These regions cause phospholipids to always align as a bilayer if there is water present. Because the hydrophobic regions do not strongly attract one another, the membrane tends to be flexible allowing variable shape and endocytosis. What maintains the overall structure of the membrane is the tendency of water to form hydrogen bonds.

2.4.3 List the functions of membrane proteins.

- Hormone binding sites
- Cell adhesion
- Channels for passive transport
- Enzymatic action
- Cell-to-cell communication
- Pumps for active transport

2.4.4 Define diffusion and osmosis.

Both diffusion and osmosis are types of passive transport. During diffusion, particles of a certain type (i.e. oxygen, carbon dioxide) move from a region of high concentration to a region of low concentration. In a living system, diffusion often involves a membrane. Osmosis involves only the passive movement of water molecules across a partially permeable membrane.

2.4.5 Explain passive transport across membranes by simple diffusion and facilitated diffusion.

Passive transport occurs in situations where there are areas of different concentrations of a particular substance. Simple diffusion involves the movement of small molecules from an area of high concentration to an area of low concentration, across a membrane. Facilitated diffusion involves a membrane with specific carrier proteins that are capable of combining with the substance to aid its movement.
2.4.6 Explain the role of protein pumps and ATP in active transport across membranes.
Active transport involves the movement of substances against a concentration gradient. Along with energy, a membrane protein must be involved for active transport to occur. First, the membrane-bound protein opens up to the inside of the cell and attaches intracellular molecules. ATP attaches to the protein causing it to change shape and release the molecules to the outside of the membrane. Next, extracellular molecules bind to different regions of the protein and this causes the release of ATP. This restores the original shape of the protein release the extracellular molecules into the cell.

2.4.7 Explain how vesicles are used to transport materials within a cell between the rough endoplasmic reticulum, Golgi apparatus and plasma membrane.
Endocytosis and exocytosis are processes that allow larger molecules to move across the plasma membrane. **Endocytosis** occurs when a portion of the **plasma membrane** is pinched off to enclose a molecule, forming a **vesicle** that can enter the cytoplasm. **Exocytosis** begins in the **rough ER**, passes through the **Golgi apparatus**, and fuses with the **plasma membrane** allowing molecules to leave the cell.

2.4.8 Describe how the fluidity of the membrane allows it to change shape, break and re-form during endocytosis and exocytosis.
The phospholipid molecules within a membrane are not closely packed together and the hydrophilic and hydrophobic properties of the different regions cause them to form a stable bilayer in water. During vesicle formation, the ends of the membrane reattach because of these hydrophilic and hydrophobic properties.

Chapter 2.5 Cell division

**Assessment Statements**

2.5.1 Outline the stages of the cell cycle, including interphase (G₁, S, G₂), mitosis and cytokinesis.

**Interphase**
- G₁: first growth phase
- S: synthesis phase
- G₂: second growth phase

**Cell cycle: Mitosis**
- Prophase: chromosomes are formed,
- Metaphase: the chromosomes move to the middle of the cell
- Anaphase: sister chromatid are split and move to opposite sides of the cell
- Telophase: The chromosomes are at each pole and the nuclear membrane begins to re-form

**Cytokinesis**
- The membrane pinches inward to form to separate cells
2.5.2 Statement. Tumors (cancer) are the result of uncontrolled cell division and that these can occur in any organ or tissue. Sometimes cells multiply so rapidly that they lose their orderly pattern of division and form a solid mass of cells. This is referred to as a tumor and can occur in all organs and tissues.

2.5.3 Statement. Interphase is an active period in the life of a cell when many metabolic reactions occur, including protein synthesis, DNA replication and an increase in the number of mitochondria and/or chloroplasts.

2.5.4 Describe the events that occur in the four phases of mitosis.

- **Prophase**: chromosomes are formed, the nuclear envelope is disintegrated and the mitotic spindle begins to form; the kinetochore of each centromere attaches to the spindle and the centromeres move toward opposite poles.
- **Metaphase**: the chromosomes move to the middle of the cell to form the metaphase plate, due to the actions of the spindle; the centromeres are now at opposite poles.
- **Anaphase**: sister chromatid are split and move to opposite sides of the cell due to shortening of the spindles; at the end of this phase the cell has a complete identical set of chromosomes.
- **Telophase**: The chromosomes are at each pole and the nuclear membrane begins to re-form; the chromosome elongate and form chromatin, the nucleolus reappears and the spindle disappears.

2.5.5 Explain how mitosis produces two genetically identical nuclei.

During mitosis DNA is replicated and identical chromosomes separate and move to opposite poles of the cell. This provides the same genetic material to each of the newly forming daughter cells.

2.5.6 Statement. Growth, embryonic development, tissue repair and asexual reproduction involve mitosis. Mitosis is a part of the cell cycle and does not occur by itself. The cell cycle describes the behavior of cells as they grow and divide.