BIOL1008: HUMAN BIOLOGY

MODULE 1: CELL STRUCTURE AND FUNCTION

1.0 ORGANISATION AND COMPLEXITY

LEARNING OBJECTIVES 1.0

- Explain the basic concepts of evolution and cell theory
- Describe how the body is made up from cells > tissues > organs that interact in systems together.
- Describe the main compartments of the body, basic orientation terminology (e.g. dorsal versus ventral), fluid distribution in the body , layers of organisational scale, dimensionality, complexity, dynamic nature of systems, and systems operating together
- Explain the major themes organising the human body including scale, concept of surface area and examples of it in operation in the human body including the lungs and digestive tract
- Explain how a single cell can survive and function in isolation.
- Distinguish the main structures and functions of a cell and its main organelles.

evolution: survival of the fittest, organisms with favourable traits survive, reproduce and pass traits onto the next generation.

cell theory: organisms are made of cells (10^3) which are the basic unit of life, coming from pre-existing cells that have multiplied - 70.7% red blood cells, 8.3% nervous system, 6.8% blood and lymph, 5.5% skin cells, 8.7% other (fat, muscle etc).

tissues: complex, organisational arrangement of cells to fulfil specific functions.

- epithelial: skin, lining of GI tract and other hollow organs
- connective: fat, bone, tendon
- muscle: cardiac, smooth, skeletal
- nervous: brain, spinal cord, nerves
- adipose: connective tissue

organs: combination of basic tissue types to carry out functions, working together in an organ system.

biological innovations:

1. Biomolecules: mapping, measuring, engineering
2. Biosystems: engineering of cells, tissues, organs (e.g. CRISPR)
3. Biomachines: interface biology and machines
4. Biocomputing: DNA computation - robotic limbs (exoskeleton, bionic eye and ear, artificial kidneys/hearts)

1.1 MOVEMENT INTO CELLS

LEARNING OBJECTIVES 1.1

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Phospholipid bilayer of the plasma membrane is semipermeable, meaning it selectively allows molecules and ions in/out of cells. It is **permeable** to water and uncharged small molecules such as oxygen and carbon dioxide. It is **not permeable** to ions (K, Na, Ca, Cl, HCO3), small hydrophilic molecules (glucose) and macromolecules (proteins, RNA).
Diffusion is the net movement of molecules from a region of high concentration to low concentration along a concentration gradient until equilibrium is reached.

- **Simple diffusion:** solute molecules can only diffuse if the membrane is permeable, constant movement of molecules through the membrane without assistance.
- Facilitated diffusion: proteins assist the movement of substances across a membrane by using **ion transporters,** transmembrane and integral proteins such as using channel proteins, carrier proteins and aquaporins.
    - Channel proteins: hydrophilic pores that allow small ions through the membrane
    - Carrier Proteins (transporters): transports large lipid insoluble molecules that cannot pass through the membrane (glucose and red blood cells)
    - Aquaporins: form pores in the membranes of cells and selectively conduct water molecules through the membrane, while preventing the passage of ions.

ISOTONIC SOLUTION:	**HYPOTONIC SOLUTION**	**HYPERTONIC SOLUTION**
Equal concentration in/out of the cell, no net flow.	Inside the cell has a higher concentration than outside, water moves into the cell and expands.	Inside the cell has a lower concentration than outside, water moves out of the cell and shrinks.

Osmosis: net movement of solvent water molecules through a semipermeable membrane into another aqueous compartment, containing a higher concentration until equilibrium is reached. **Tonicity** refers to the osmotic pressure gradient.

Active transport: ATP breakdown energises proteins, transporting substances against the concentration gradient.

- Endocytosis: When a large particle moves into a cell, the membrane changes shape to surround the particle and engulf it.
- Exocytosis: Specialised substances are transported to the external environment by fusing with membrane and releasing content into the cell.
- Phagocytosis: solid particle is engulfed
- Pinocytosis: fluid particle pinocytosis

Sodium-Potassium Pump: all cells have a negative membrane potential. The Na^+/K^+-ATPase enzyme is active using an opening and closing mechanism. For every ATP molecule that the pump uses, three sodium ions are exported and two potassium ions are imported.

1.2 HOMEOSTASIS, SIGNALLING AND FEEDBACK LOOPS

LEARNING OBJECTIVES 1.2

- Explain negative and positive feedback with physiological examples
- Describe an example of homeostasis
- Describe how sensors and feedback systems operate to maintain homeostasis in negative feedback loops
- Describe the endocrine system and hormones
- Explain how hormones allow even distant cells to communicate
- Explain the roles of messengers and receptors in cell communication
- Describe the difference between lipid soluble and water soluble hormones
- Explain the basic mechanism of steroid hormone responses
- Explain the difference between first messengers and second messengers, with cAMP as an example
- Explain the basis of how the body regulates extracellular fluid osmolality
- Explain how oxytocin and ADH work

Homeostasis is the maintenance of a stable internal environment when subjected to change in the external environment. stimulus → receptor → control centre → effector → response

- Negative feedback loops: counteract changes from set points to return equilibrium (e.g. body temperature, glucose)
- Positive feedback loops: amplify initial stimuli to move system away from its start point (e.g. childbirth, blood clotting)

Endocrine System: hormones - chemical messenger molecules - are secreted into the bloodstream through *endocrine glands*. The ductless glands' secretions - *exocrine* - discharge and circulate into blood/lymphs.

Functions of the Endocrine System: *reproduction, growth and development* (sex steroids), *maintenance of internal environment* (aldosterone, parathyroid hormone, vitamin D), *energy production, usage and storage* (insulin, glucagon, TSH, cortisol)

Signal Amplification: In response to an external stimulus, a signal leads to a cell response which is amplified through *phosphorylation cascades* (kinase enzymes transfer phosphate and activate target proteins). Secondary messengers generally operate through activation of protein kinases, key intermediate molecules whose presence is a signal and acts as amplifiers/intracellular ligands.

GCPR signalling and amplification:

- Reception: Signal molecule (such as epinephrine) binds to receptor → G proteins bind to GTP (same as ATP but guanosine instead of adenosine)
- Transduction: Inactive G protein-coupled receptor and inactive adenylyl cyclase are activated. Adenylyl cyclase turns ATP into cyclic AMP (cAMP) which activates phosphorylase kinases (cascade commences).
- Response: Active glycogen produces glucose-1-phosphate

Calcium (acts as second messenger): levels are low in the human body meaning a dramatic increase acts a call to action, iterating and conforming protein activity. Membrane receptors are activated, calcium floods cells quickly and triggers neurotransmitters to alter cellular activity (signals between cells and exocrine process - cardiac myocyte).
Steroid Receptors: mechanism of hormones that readily enters cells (e.g. oestradiol secreted from ovaries)
The pituitary gland:
The posterior pituitary: 2 primary hormones

- Oxytocin: uterine contractions, breast milk ejection
- ADH (vasopressin): primary action is to prevent kidney water loss in addition to responding to a rise in blood osmolarity and fall in blood pressure/volume.