BIO10008 Study Notes – Detailed Notes

About these notes

These notes cover all of the content of the BIOL10008 Introductory Biology: Life's Machinery. They are organised into 24 numbered concepts under the 5 central topics: Cells and Molecules; Energy, Metabolism, and Signalling; Multicellular Organisms; Genes, Inhereitence, and Genetic Technology. Each concept is split into numbered subsections that follow the order of the source. Comparisons are set out in tables, key terms are in bold, and step-by-step processes are numbered.

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Concept 1: What is life?

1.1 How we define life

Life is defined by cell theory together with a set of shared characteristics.

Cell theory

- All living things are made up of cells.
- The cell is the smallest unit of life.
- Cells come from pre-existing cells. Spontaneous generation cannot occur.

Characteristics of life. Living things:

- grow and change (develop)
- are made of cells
- contain genetic information; the DNA code is shared across life, which reflects the shared ancestry of all living things
- make and use new molecules (metabolism)
- extract and use energy
- respond to their environment
- reproduce and evolve over generations

Are viruses alive? Viruses sit on the boundary of the definition.

Case for life	Case against life
They contain nucleic acid (DNA or RNA)	They are not made of cells
They replicate, but only by using a host cell	They cannot replicate independently
They evolve	They have no metabolic processes of their own
	They cannot extract energy

Because they fail most of the criteria on their own, viruses are generally treated as non-living entities that depend on living hosts.

1.2 Origins of life: two key terms

- **Cyanobacteria:** microscopic photosynthetic bacteria found naturally in all types of water. Their oxygen-producing photosynthesis changed the early Earth (see Topic 3).
- **Eukaryote:** an organism whose cells contain a nucleus and other membrane-bound organelles.

Concept 2: Molecules of life

2.1 Molecules of life and carbohydrates

- **Monomers** are atoms or small molecules that bond together to form more complex **polymers**.
- All of life is made from four major groups of large molecules (macromolecules), plus water: **carbohydrates, proteins, nucleic acids and lipids**.
- Macromolecules are built from smaller units by **condensation** (dehydration) reactions, which release water, and are broken down by **hydrolysis** reactions, which use water.

Carbohydrates are a source of energy (for example glucose). Their general formula is (CH2O)n. They are split into three groups by the number of sugar units:

Class	Units	Notes
Monosaccharides	One sugar	For example glucose
Disaccharides	Two sugars	Two monosaccharides joined by a glycosidic bond, a covalent C–O–C (ether-type) link formed by condensation
Polysaccharides	Many sugars	Many monosaccharides bonded together, for example starch, glycogen and cellulose

Starch

- A natural polymer of glucose (alpha-glucose); the main energy-storage carbohydrate of plants.
- Being a large, compact molecule, it has a much smaller osmotic effect (water-absorbing capacity) than the same number of free glucose molecules. It is also used as an emulsifier and thickener in foods.
- Its branched structure means that many glucose units can be released at once, so starch is readily digested to supply glucose for respiration.

Cellulose

- A complex carbohydrate and the most abundant organic polymer on the planet.
- The main substance of the cell walls of plant cells, providing strength and rigidity.
- Made from glucose and structurally very similar to starch, but built from the **beta** ring form of glucose rather than the alpha form. This makes the chains straight and unbranched.
- Linear cellulose chains lie side by side and form fibrils. The fibrils hold their shape through hydrogen bonding between the hydroxyl groups of neighbouring chains, which gives the cell wall its strength.

2.2 Nucleic acids

- **DNA** (deoxyribonucleic acid) is double stranded.
- **RNA** (ribonucleic acid) is single stranded.
- The bases fall into two groups. **Pyrimidines** (single ring): cytosine, thymine and uracil. **Purines** (double ring): adenine and guanine.
- A **nucleoside** is a sugar joined to a base. Adding phosphate groups gives a nucleotide, the monomer of a nucleic acid.

Ribosomes

- A small structure made of two subunits, each made of ribosomal RNA and proteins.
- They carry out protein synthesis in two locations in eukaryotes: free in the cytosol (free ribosomes), and on the outside of the endoplasmic reticulum or the nuclear envelope.
- Prokaryotic ribosomes are 70S and eukaryotic ribosomes are 80S.

Classification of bacteria by Gram staining

Feature	Gram positive	Gram negative
Cell wall	Simple: a single thick layer (20–80 nm)	Structurally complex: thin wall (8–10 nm) with an outer membrane
Peptidoglycan	Thick, multilayered	Thin, a single layer
Outer membrane	Absent	Usually present
Lipid content	Low	20–30%
Antibiotics	More susceptible	Very resistant
Toxicity	Usually less toxic	Usually more toxic
Gram stain	Retains the stain and appears purple	Does not retain the stain and appears pink or red with the counterstain

3.3 The function and abundance of prokaryotes

Prokaryotes are ubiquitous (found everywhere) and diverse. Many archaea are thermophilic (heat loving), acidophilic (acid loving), or both.

- ***Sulfolobus***: lives in hot sulfur springs at 70–75 °C. The springs are very acidic (pH 2–3), yet these thermophiles keep an internal pH of 5.5–7.
- ***Pyrolobus fumarii***: found around deep-sea hydrothermal vents. It grows at temperatures up to about 106 °C and becomes metabolically inactive below about 90 °C.
- ***Methanothermococcus okinawensis***: survives without oxygen by combining hydrogen and carbon dioxide, and releases methane as a waste product.

Prokaryotes and humans

- Bacteria live on and in us, and many are important, for example those in the gut. Some bacteria cause disease because of the toxins they produce.
- **Recycling:** at the Werribee sewage treatment plant, bacteria clean up wastes and toxins in human waste until the water is safe enough to release into Port Phillip Bay.
- **Genetically modified (GM) bacteria** make many pharmaceuticals. They have been engineered to produce human insulin, human growth hormone (hGH) and human interferon.

Cyanobacteria are major primary producers and have had huge impacts on life on Earth: they caused the Great Oxygenation Event, and they gave rise to the chloroplasts of land plants (see Concept 4).

Concept 4: The eukaryotic cell

4.1 Prokaryotes versus eukaryotes

	Prokaryotic cells	Eukaryotic cells
Similarities	Plasma membrane, ribosomes, their own genetic material, cytoplasm	The same
Organelles	No membrane-bound organelles	Contain membrane-bound organelles
Cell wall	Peptidoglycan (in bacteria)	Cellulose, hemicellulose, pectin, lignin and soluble protein in plants
Cell structure	Simple	Complex

Diversity: prokaryotes are far more diverse than eukaryotes.

4.2 Key organelles of the eukaryotic cell

The nucleus: the command centre (the "brain") of the cell

- Surrounded by a double membrane, the nuclear envelope. A double membrane has two bilayers, which is four layers of phospholipids.
- **Nuclear pores** control the movement of molecules across the envelope.
- The **nucleolus** is the subregion of the nucleus where ribosomal genes are transcribed (ribosome biogenesis).
- DNA is in long strands wound around histone proteins, forming chromosomes. Different organisms have different numbers of chromosomes.
- RNA transcribed from DNA leaves the nucleus through the pores and is translated in the cytoplasm.
- It is the site where gene transcription is turned on or off.
- It is continuous with the endoplasmic reticulum.

Chromosomes

- Each chromosome contains one long DNA molecule.
- Each chromosome is made of chromatin, a complex of proteins and DNA.
- Each eukaryotic and prokaryotic species has a characteristic number of chromosomes.

Mitochondria

- The site of ATP synthesis; they carry out the aerobic respiration of eukaryotic cells.
- Surrounded by two membranes: a smooth outer membrane and a highly convoluted inner membrane, whose inward folds are called **cristae**. The cristae increase the surface area, which maximises the activity taking place on it.

16.2 Animal organs

Organs are composed of tissues

- A functioning organ brings together the four tissue types. The defining feature is that it consists of an epithelium and one or more of the other kinds of tissue.
- The **small intestine** is an example:
    - The inner surface is a sheet of epithelial cells that secrete digestive enzymes into the lumen, secrete hormones and absorb nutrients. Its wall forms folds lined with finger-like projections called villi, which are themselves covered in microvilli, giving a large SA.
    - Outside the inner surface is the mucosa, made of connective tissue. This layer contains blood vessels, neurons, and glands made up of secretory epithelial cells.
    - Smooth muscle enables the gut to mix the ingested food with digestive enzymes and move it through the alimentary canal.
    - A network of nervous tissue innervates the muscle, controlling and coordinating its contractions, and provides a sensory function.
    - An outer layer of epithelial and connective tissue covers the gut and other organs in the abdominal cavity, and lines the abdominal cavity.

Organ systems are composed of organs

- An organ system is a group of organs working together to carry out certain functions that achieve a common purpose. The digestive system (gastrointestinal system) has the common goal of digesting food.

Region	What happens
Mouth, teeth and tongue	Break up the food that has been ingested. Salivary glands release amylase, which begins the breakdown of carbohydrates
Stomach	Pepsin and HCl begin the digestion of protein
Duodenum (small intestine)	Most digestion occurs here. Pancreatic enzymes and bicarbonate ions are secreted from the pancreatic duct to digest food and neutralise the acid from the stomach. Bile, made in the liver and stored in the gallbladder, emulsifies fats, increasing their surface area and enhancing their breakdown by fat-digesting enzymes
Small intestine (epithelium)	The epithelial cells release many enzymes that complete the digestion of sugars and proteins, and about 90% of nutrients are absorbed here
Liver	Acts as the main controller of blood glucose levels
Large intestine, rectum and anus	Water, inorganic ions and vitamins are removed, and the faeces pass through the rectum and out of the anus to eliminate waste

Meiosis versus mitosis

Feature	Mitosis	Meiosis
Occurs in	Most eukaryotic cells (somatic cells)	Germ cells
Divisions	One: four stages	Two: the four stages twice, without an intermediate DNA synthesis phase
Product	Two identical diploid daughter cells	Four genetically distinct haploid daughter cells (a reductional division)
Prophase	Shorter. No pairing of homologous chromosomes and no recombination, so all daughter cells are genetically identical	Prophase I is the longest phase, with five substages. Homologous chromosomes pair to form the synaptonemal complex and recombine to produce four genetically diverse chromatids
Metaphase	Individual chromosomes assemble along the equator	Metaphase I: pairs of homologous chromosomes align on the equator
Cohesin	Cohesin complexes holding the sister chromatids are removed at the end of metaphase, allowing the sister chromatids to separate and move to opposite poles	In meiosis I, only the cohesin on the chromosome arms is detached at the start of anaphase I, while that around the kinetochore remains intact. Even as homologues are pulled to opposite poles, the sister chromatids stay attached and migrate together
Anaphase	Separation of the sister chromatids, giving identical diploid daughter cells	Anaphase II is similar to mitosis (separation of sister chromatids), but gives non-identical haploid cells

- Daughter cells arising from meiosis are more likely to have chromosome segregation errors than those arising from mitosis. These errors can result in an incorrect number of chromosomes, which leads to diseases such as Down syndrome.