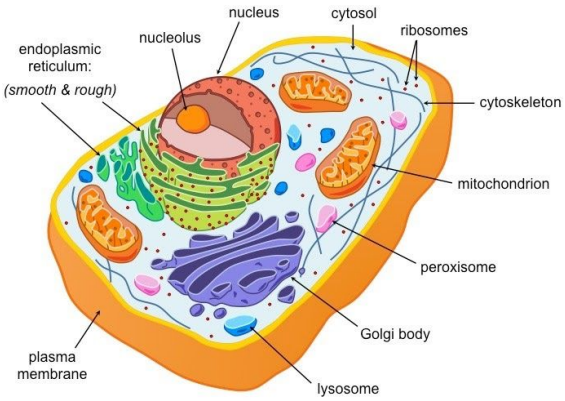
CBG Final Exam Notes

Cell Biology and Genetics (University of Technology Sydney)

INTRO TO CELLS

***Eukaryotic Cell* - an organism that contains genetic information in the nucleus**



Eukaryotic Organelles

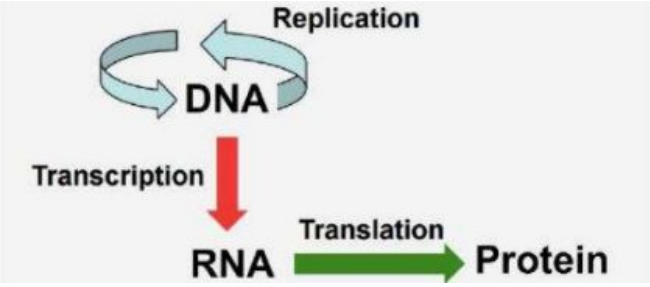
- **Mitochondria -** Cellular respiration and energy production
- **SmoothEndoRet -** Lipids and steroid synthesis
- **RoughEndoRet -** Protein synthesis, Translation
- **Nucleus -** Storage of DNA, Control cell activity
- **Nucleolus -** Develop ribosomes
- **Plasma Membrane -** Selectively permeable,
- **Golgi Apparatus -** Processes and packages proteins
- **Peroxisome -** break down fatty acids for fuel for respiration
- **Lysosome -** Digests nutrients, proteins, fats and carbs

Intercellular Junctions

- **Plasmodesmata** - Channels that perforate plant cell walls. Water and small solutes pass through.
- **Tight junctions** - Neighbouring cells are pressed together, preventing leakage of extracellular fluid.
- **Desmosomes** - Fasten cells together into strong sheets.
- **Gap junctions** - Cytoplasmic channels between adjacent cells. Ions, water and sugars.

NUCLEIC ACIDS & DNA REPLICATION

Central Dogma of Life



- **Genes** are stretches of DNA that contain the instructions for the production of a protein
- **DNA** is transcribed to mRNA which is translated to make a **protein**
- **Transcription** is the synthesis of RNA using information in the DNA
- **Translation** is the synthesis of polypeptide using the information in the mRNA

RNA

Messenger RNA (mRNA)

RNA copy of gene, made by transcription .

Function: Take sequence from gene to ribosomes where it is translated into amino acids

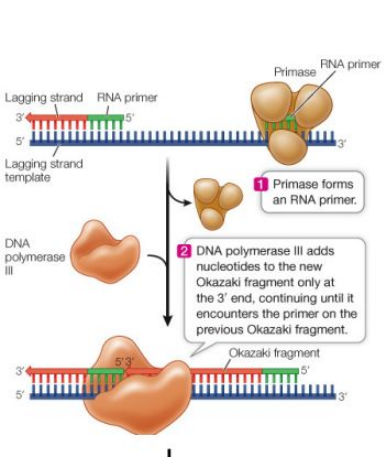
Transfer RNA (tRNA)

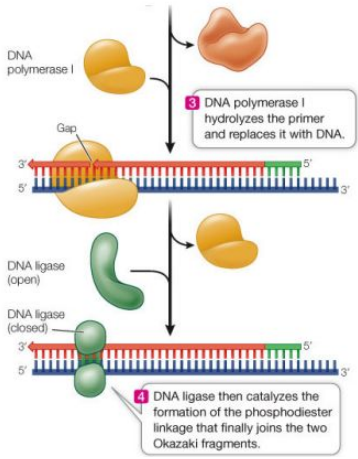
Function: Bring amino acid to the mRNA for protein synthesis

Ribosomal RNA (rRNA)

Function: Reads the mRNA to translate it to amino acids

DNA Replication





THE CELL CYCLE & CELL DIVISION

Cell Cycle Phases

G1 - Decision whether to divide from the reproductive signal

S - DNA Replication

G2 - Ensures all chromosomes have been replicated correctly

M - Mitosis begins

Cell Cycle Signals

Cdks

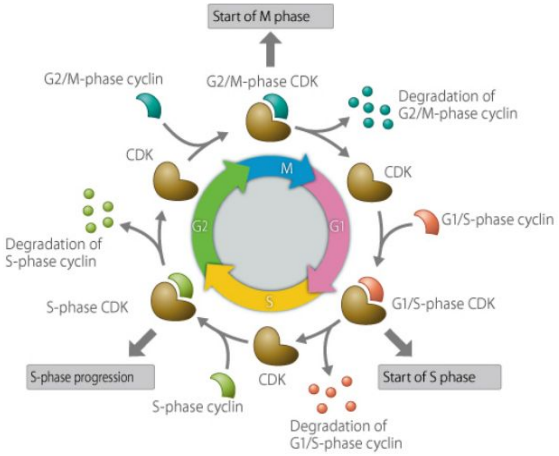
- Cyclin-dependant kinases
- Phosphorylates cellular proteins - activates or inactivates proteins

Cyclins

- Regulatory proteins
- Levels cycle in the cell

Cdk-cyclin complex

- Triggers passage through different stages of cell cycle



Mitosis and Meiosis

						OUTCOME
PROCESS	DNA synthesis	Synapsis of homologous chromosomes	Crossover	Homologous chromosomes line up at metaphase plate	Sister chromatids line up at metaphase plate	Number and genetic composition of daughter cells
MEIOSIS	Occurs in S phase of interphase	During prophase I	During prophase I	During metaphase I	During metaphase II	Four haploid cells at the end of meiosis II
OSIS	Occurs in S phase of interphase	Does not occur in mitosis	Does not occur in mitosis	Does not occur in mitosis	During metaphase	Two diploid cells at the end of mitosis

WATER AND BUFFERS, BIOCHEMISTRY

Buffers

- The internal pH of most living cells must remain close to pH 7.
- Buffers are substances that minimise changes in concentrations of H+ and OH– in a solution.
- Most buffers consist of an acid-base pair that reversibly combines with H+
- Eg. Blood - Carbonic Acid (acid) and Bicarbonate (base)

Carbon Compounds

- Carbon has four valence electrons = can form 4 covalent bonds
- Allows the formation of large, complex molecules

Isomers

Variants in the architecture of a molecule. Same molecular formula, different structure. Different function.

Carbohydrates

- Sugars and their polymers. Simplest sugars are monosaccharides (monomers).
- Disaccharides consist of two monosaccharides.
- Macromolecules are polysaccharides

Monosaccharides

- Monosaccharides are polar and hydrophilic –Will dissolve in aqueous/polar solutions only
- Major nutrient source for cells (especially glucose)
- Anomers: Geometric Isomers that differ at the carbonyl/anomeric carbon

LIPIDS & MEMBRANES

Lipids

Fats, acids.
Hydrophobic (non-polar).
Uses: Energy storage.Protection. Insulation. Lipid membrane.

Types of Lipids

Non-polar e.g. Triacylglycerol.
Polar e.g. Phospholipid.

Groups

Fatty Acids	- Energy source, saturated (all single C-C bonds), unsaturated (1+ double C bond), poorly soluble - Free fatty acid-carboxyl acid head group (COOH)
Triaclyglycerols	- 3 fatty acids bound to glycerol. Highly reduced, soluble in organic solvents - Non-polar, saturated = C-C - Unsaturated = at least 1 double c bond

Phospholipids	- Amphipathic, bridge between nonpolar and polar solvents
Sterols	- Steroid nucleus, fatty acyl chain with small polar head

Cell Membrane

- Selective barrier that allows sufficient passage of oxygen, nutrients, and waste to service the volume of every cell.
- Double layer of phospholipids.

Transport Processes

- Diffusion - movement of molecules from high to low concentration, across a biological membrane is passive transport.
- Osmosis - the diffusion of water across a selectively permeable membrane.
- Tonicity - the ability of a surrounding solution to cause a cell to gain or lose water
- Isotonic solution - solute concentration is the same as that inside the cell: no net water movement across the plasma membrane
- Hypertonic solution - solute concentration is greater than that inside the cell: cell loses water
- Hypotonic solution - solute concentration is less than that inside the cell: cell gains water
- Osmoregulation - the control of solute concentrations and water balance is a necessary adaptation for life in such environments.

Passive Transport	- The movement of molecules where no energy is required, molecules move in response to a concentration gradient - Passive transport is diffusion of a substance across a membrane with no energy investment
Facilitated Diffusion	- Passive transport aided by transport proteins - Proteins speed up the passive movement of molecules by allowing the passage of hydrophilic substances - Channel proteins → provide corridors that allow specific molecule/ ions through hydrophilic channel - Carrier proteins → bind to molecules and change shape to shuttle them across the membrane. Specific for substance.

Active Transport	- Needs energy to move solutes against gradients
	- Energy in the form of ATP (adenosine Triphosphate)
	- Performed by specific proteins embedded in the membranes
	- Active transport allows cells to maintain concentration gradients that differ from their surroundings
	- E.g. Potassium Pump
	  - Uses an antiporter to move 3Na out of the cell and 2K into the cell
	  - ATP energy is used to change the conformation of the carrier protein

Maintaining Membrane Potential

- Membrane potential is the voltage difference across a membrane.
- Voltage is created by differences in the distribution of positive and negative ions.

Electrogenic pump is a transport protein that generates voltage across a membrane
The sodium-potassium pump **is the major electrogenic pump of animal cells**
The main electrogenic pump of plants, fungi, and bacteria is a **proton pump**
Electrogenic pumps help store energy that can be used for cellular work

Bulk Transport across the Plasma Membrane

Exocytosis
- Transport vesicles migrate to the membrane, fuse with it, and release their contents.
- Many secretory cells use exocytosis to export their products.

Endocytosis
- The cell takes in macromolecules by forming vesicles from the plasma membrane.
- Reverse of exocytosis.
- 3 types: Phagocytosis (cellular eating), Pinocytosis (cellular drinking), Receptor-mediated endocytosis.

PROTEINS AND ENZYMES

Proteins

- Function: Some proteins are enzymes, antibodies, transporters.
- Proteins have plenty of functions. Strong role in homeostasis.
- Structure: - Polymers (1 protein is many amino acids joined together to make a macromolecule)

Polypeptides and Proteins

Proteins are a polypeptide and a polypeptide is lots of amino acids joined together with lots of peptide bonds. Proteins have specific sequences, which gives specific structure and function.

Denaturation

- A change called denaturation causes the protein to unravel and lose its native shape, thus losing its function.
- The denatured protein is biologically inactive and useless.
- Denaturation Factors: pH, temp, reducing agents, ionic strength (salt concentration), changes in polarity of solutions

Enzymes

- All enzymes are proteins. - Not all proteins are enzymes.
- Biological catalyst – Increases reaction rates.
- Binds to and transforms specific molecules. These molecules are known as substrates. Substrates bind at the active site.
- Enzymes are specific. 1 enzyme, 1 substrate, 1 reaction.

Environmental Conditions

Ionic strength - amount of salt dissolved in a solution If solution is organic or aqueous

pH - e.g. pepsin is a digestive enzyme in the stomach and works best at a pH 2

Temperature -.e.g. Digestive enzymes and metabolic enzymes are set to be highest active at body temperature of 37 degrees

Enzyme Inhibitors and Regulators

Enzyme Regulation

Negative feedback control – turns off a process. End product acts on enzyme 1 to turn it off. Turns it off by a conformational change in the catalytic site

Enzyme Inhibitor

A competitive inhibitor mimics the substrate, competing for the active site

A noncompetitive inhibitor impedes enzymatic reactions by bind to another part of the enzyme, causing the enzyme to change its shape.

CELLULAR PROCESSES

Metabolism

All chemical reactions of an organism

Functional cluster of metabolic reactions is a metabolic pathway

- Catabolism - Breakdown of large molecules
- Anabolism - Synthesis of larger molecules

Gibbs Free Energy Change

$$\Delta G = \Delta H - T\Delta S$$

Favourable reaction	Unfavourable reaction
$\Delta H < 0$	$\Delta H > 0$
$\Delta S > 0$	$\Delta S < 0$
$\Delta G < 0$	$\Delta G > 0$

Exergonic and Endergonic Reactions in Metabolism

Exergonic - Energy is released, Favourable - Spontaneous (no energy is needed for the reaction to go forward), -ve delta G, Delta G < 0

Endergonic - Unfavourable - not spontaneous, Reaction favours reactants, +ve Delta G, Delta G > 0

ATP Powering Cellular Work

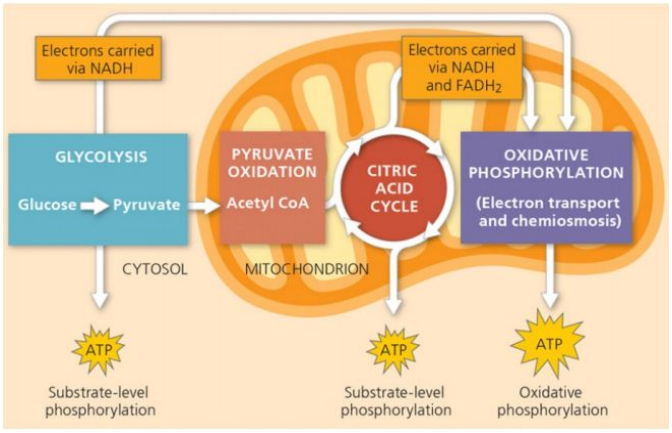
- Chemical work – driving endergonic reactions
- Transport work – moving substances against direction of spontaneous movement
- Mechanical work – beating of cilia, contraction of muscles etc.

Hydrolysis of ATP

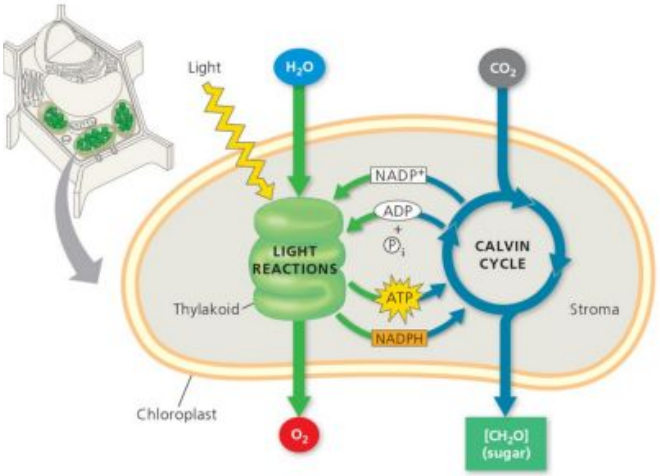
- Hydrolysis can break the bonds between the phosphate groups of ATP
- Exergonic reaction - Releases ~13 kcal/ 1M of ATP in cell conditions

Cellular Respiration

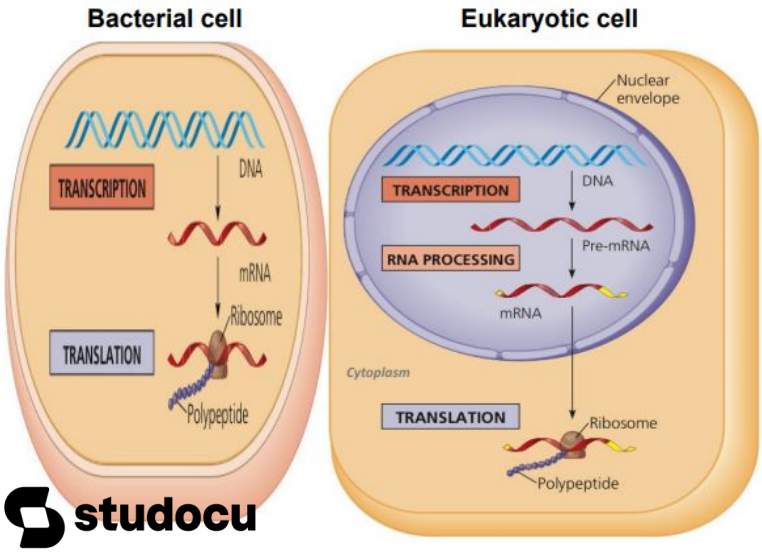
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$



Photosynthesis



GENE EXPRESSION



GENETICS

Mendel's Laws of Inheritance

1. **Law of Segregation:** When gametes form, alleles are separated so that each gamete carries only one allele for each gene
2. **Law of Independent Assortment:** The segregation of alleles for one gene occurs independently to that of any other gene*
3. **Principle of Dominance:** Recessive alleles will be masked by dominant alleles

Complete dominance – one allele is completely dominant over the other, therefore heterozygotes can't be distinguished from dominant homozygotes
Incomplete dominance – neither allele is completely dominant resulting in heterozygotes that are an intermediate phenotype
Codominance - both alleles affect the phenotype in different ways. Both are expressed, both dominant phenotypes are present in offspring - such as roan cattle and Erminette

Multiple Alleles - Mendel studied that had two possible alleles - In reality, most genes have more than two E.g. Blood groups
Pleiotropy - The principle that one gene can have multiple effects - Many humans are pleiotropic, often becoming apparent in disease
Epistasis - Where expression of one gene affects the expression of another gene E.g. Pigment in coat colour of dogs being affected by other genes

Chromosomal Abnormalities

- Nondisjunction– occurs during meiosis when homologous chromosomes don't separate properly
- Results in gametes with one too many or one too few chromosomes

Aneuploidy - an abnormal number of chromosomes
Monosomy - only one copy of a chromosome
Trisomy - three copies of a chromosome

CELL COMMUNICATION

4 Basic Mechanisms

Direct Contact

- Molecules pass from cell to cell via cell junctions
- Molecules on the surface of one cell are recognised by receptors on the adjacent cell

Paracrine Signalling

- A signal released from one cell has an effect on neighbouring cells

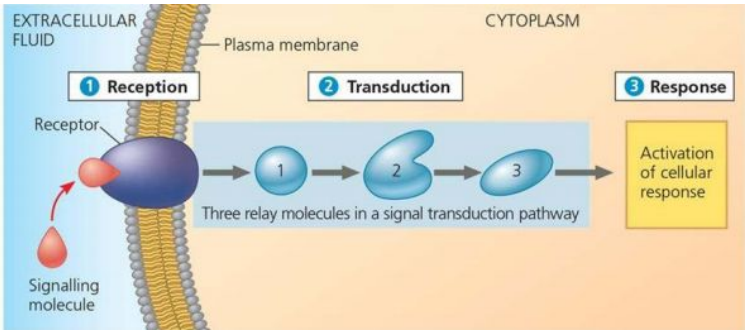
SynapticSignalling

- Nerve cells release neurotransmitters, which bind to receptors on nearby cells

EndocrineSignalling

- Hormones released from a cell affect other cells throughout the body

Cell Signalling Stages



Stage 1: Reception

- Involves a signalling molecule binding to a receptor (Ligand)
- The binding between a signalling molecule (ligand) and its receptor is highly specific
- Receptors can be:
  • Intracellular – located within the cell –Ligands tend to be hydrophobic/very small
  • Cell-surface receptors – located on the plasma membrane of the cell

Stage 2: Transduction

- When a ligand binds to a receptor protein, the cell has a response
- Signal transduction - the events within the cell that occur in response to a signal
- A signal transduction pathway is a series of steps by which a signal on the cell surface is converted into a specific cellular response

Stage 3: Response

- The transduced signal finally triggers a specific cellular response
- Examples: »Regulation of gene transcription/protein synthesis »Regulation of protein activity »Regulation of cell division

Reception

1. **G-protein coupled receptors** – aG-protein (bound to GTP) assists in transmitting the signal
2. **Receptor Tyrosine Kinases** – receptor is an enzyme that is activated by the ligand
3. **Ion Channel Receptors** – ion channel that opens in response to a ligand

Transduction

Protein Phosphorylation

• In many pathways, the signal is transmitted by a cascade of protein phosphorylations
• Protein kinases transfer phosphate fromATP to protein, a process called phosphorylation
• Protein phosphorylation usually activates the protein

The specificity of cell signalling and coordination of the response

- Even the same signal can have different effects in cells with different proteins and pathways
- Pathway branching and 'cross-talk' further help the cell coordinate incoming signals
- Scaffolding proteins are large relay proteins to which other relay proteins are attached. Increases the signal transduction efficiency, by grouping together different proteins involved in the samepathwa

Apoptosis

• Apoptosis is programmed cell death
• Apoptosis integrates multiple cell-signalling pathways
• A cell is chopped and packaged into vesicles that are digested by scavenger cells
• Apoptosis prevents enzymes from leaking out of a dying cell and damaging neighbouring cells