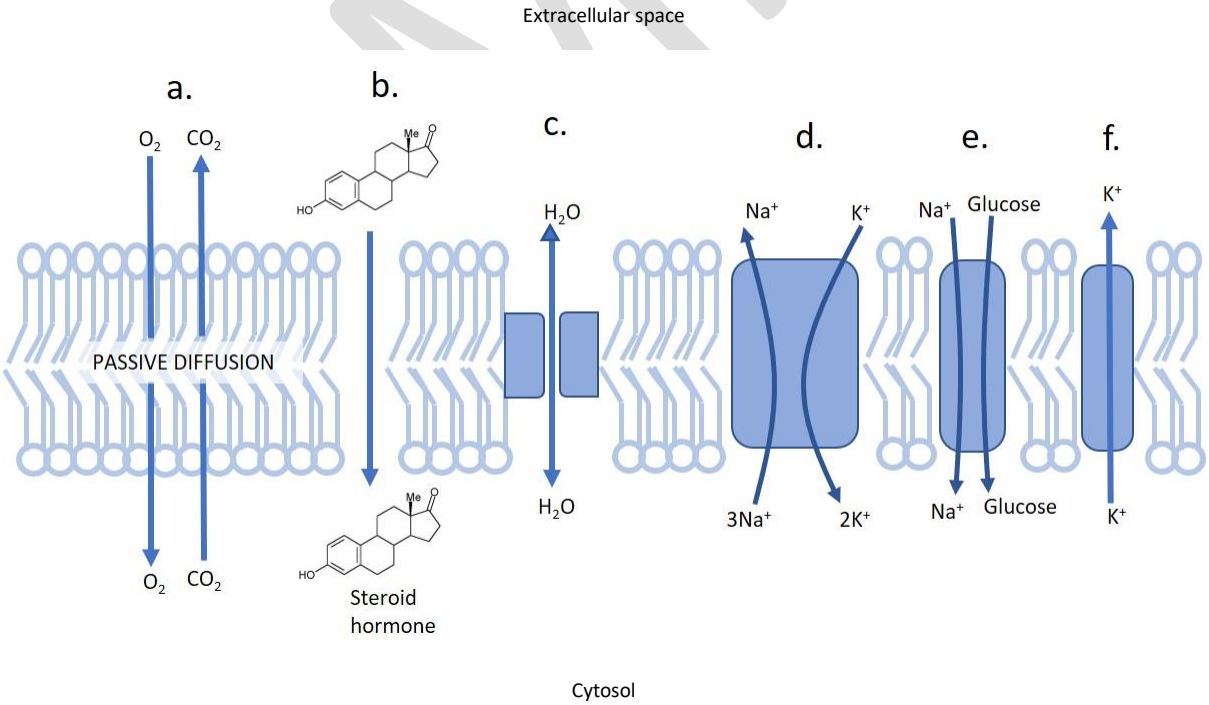
Contents

MODULE 1 – PRINCIPLES OF CELL FUNCTION

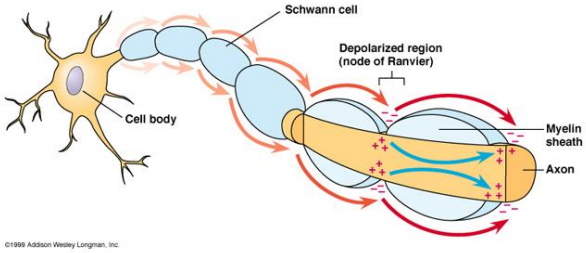
Transport across the cell membrane

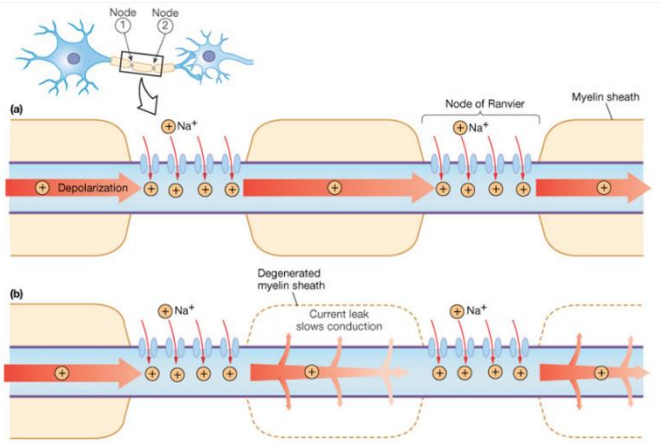


The phosphlopid bilayer is made up **of amphipatic molecules** with hydrophilic phosphate heads (polar, negatively charged), which result in a net -ve charge on the cytosolic/extracellular faces of the plasma membrane, and hydrophobic lipid tails.

OLIGODENDROCYTES/SCHWANN CELLS

- CNS/PNS
- Form myelin sheaths around exons
- Myelin sheath serves as insulation for neuron axons, dividing the axon into individual Schwann cells. The membrane is exposed to the extracellular fluid only at the nodes of Ranvier, therefore saltatory conduction can propagate action potentials faster (shorter latency) than unmyelinated axons. The degree of myelination can vary between organisms, due to many factors, many of which are related to the genome.





Depolarising current during an AP at one node of Ranvier spreads along the interior of the axon to the next node, where voltage-gated Na+ channels enable re-excitation

Myelination allows for longer neurons and for more complex organisms to function

Multiple Sclerosis

Multiple Sclerosis (MS) is a disease which causes demyelination in brain and spinal cord neurons causing a variety of physiological and psychiatric problems, such as spasming and loss of feeling and motor control. Demyelinated neurons result in slow or distorted propagation of action potentials, and a sensitivity to temperature (no insulation). Hence, MS patients cannot cope with the high frequency and high-speed conduction caused by elevated temperatures. This is why high temperatures can trigger spasms and worsen symptoms in MS patients, as signals are not being transported properly to the brain and throughout the body.

Types of neurons

Sensory neurons

- Transmit information about external stimuli (light, smell) or internal stimuli (blood pressure)
- Cell body located on the axon

Interneurons

- Located in the brain
- Local circuits connecting neurons to the brain

Motor neurons

- Extend to processing centres e.g. tells muscle to contract

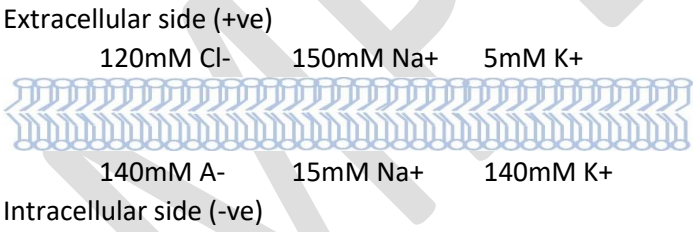
Action potentials

An action potential (AP) is a local and temporary depolarisation followed by a hyperpolarisation in the concentration gradient of a neuron's membrane. Depolarisation occurs when sodium voltage-gated ion channels open and sodium ions influx the cytoplasm of the cell causing the cell membrane potential to rise and peak. A threshold voltage must be reached to trigger the opening of these sodium channels, and this threshold varies between nerve fibres within a nerve.

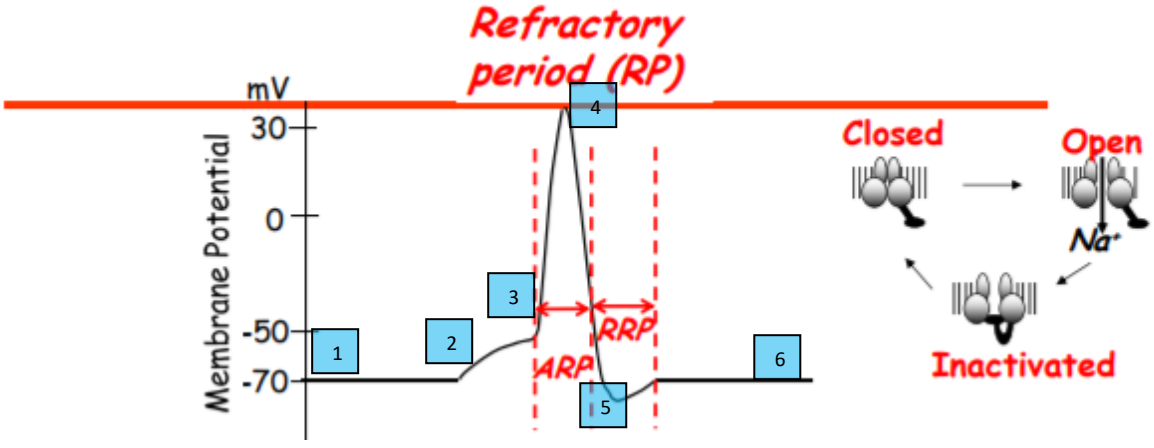
The compound action potential (CAP) is the sum of all individual fibre APs firing in a nerve bundle. Hence, as stimulus strength increases, more fibres reach their threshold voltage and are recruited to propagate APs, resulting in higher overall CAP. The CAP voltage will reach a maximum when all fibres in the nerve have been recruited (maximum number of action potentials reached).

Resting membrane potential

- Many open K+ channels, few open Na+/Cl- channels → build-up of **negative charge inside the cell**
- Neuron equilibrium potential = about -70mV

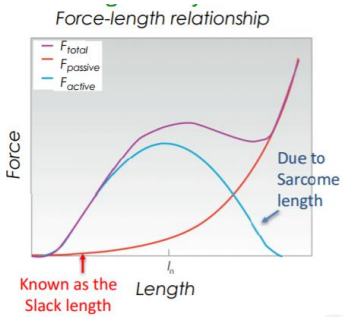


AP mechanism



1. **Resting state** – voltage-gated ion channels closed
2. **Stimulus** – causes a few Na+ channels to open
3. **Depolarisation** (++++++++) (if threshold is reached) lots Na+ channels open; Na+ rushes in…..

Hill's mechanical model of the muscle-tendon unit



- ACTIVE: Contractile component (CC) = muscle fibres, actin and myosin cross bridges
- PASSIVE: Series elastic component (SEC) = intracellular titin & tendon
- PASSIVE: Parallel elastic component (PEC) = connective tissue within the muscle: epimysium, perimysium, endomysium

Types of skeletal muscle

SLOW TWITCH	FAST TWITCH	
Type 1 fibres	Type 2A	Type 2B
Slow oxidative motor units Low force Fatigue resistant Aerobic respiration High myoglobin Many mitochondria	Fast oxidative motor units Higher force Less fatigue resistant Aerobic respiration High myoglobin Many mitochondria	Fast glycolic motor units Most force Fatigues quickly Glycolysis Low myoglobin (white muscle) Few mitochondria

Henneman's size principle

Smaller motor units are recruited first then larger ones → to produce more force

Types of contraction

1. Eccentric (dynamic) → lengthening (movement down) HIGHEST FORCE
2. Isometric (static) → same length
3. Concentric (dynamic) → shortening (movement up) LEAST FORCE

Role of the skeleton

Support → e.g. ribs support lungs from collapsing, e.g. pelvis for pelvic organs
Protection → e.g. skull protects brain, vertebral column for spinal cord
Movement → muscles need rigid structure to attach to when contracting

206 bones → 80 axial (head/trunk) and 126 appendicular (appendages)

Motor unit

- 1 motor neuron, its motor axon, and all muscle fibres it innervates
- Includes EPSP and IPSP input from descending pathways, spinal interneurons and afferent fibres
- Every excitatory input reaches firing threshold → AP is generated
- Every AP in motor neuron generates an AP in muscle unit's muscle fibres → every AP generates a little bit more force

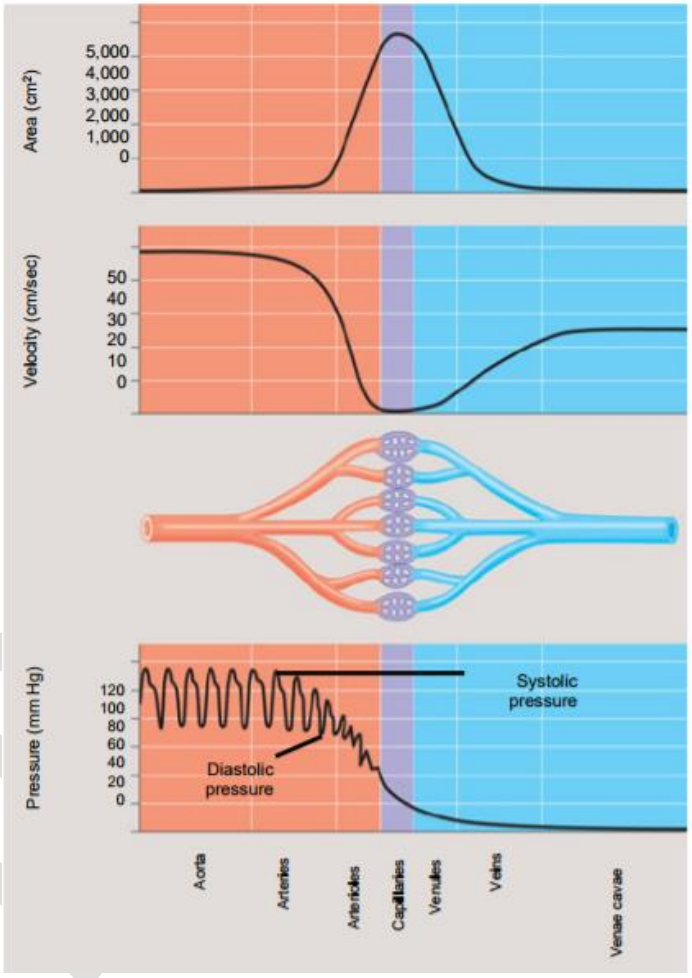
Physiological cross-sectional area

$$PCSA = \frac{muscle\ volume}{fiber\ length}$$

A good predictor of muscle force (Muscle structure & size also influence force)

Blood flow velocity & pressure

- Velocity slowest in capillaries (high resistance and large total cross-sectional area)
- **Blood pressure** = hydrostatic pressure that blood exerts against the wall of a vessel
- **Systolic pressure** = pressure in arteries during ventricular systole (highest pressure in arteries)
- **Diastolic pressure** = pressure in arteries during diastole (relax)



- **<u>To measure blood pressure:</u>**

  Rubber cuff arm to increase pressure (closes artery downstream)

  When you release cuff at systolic pressure → creates turbulent flow

  Reading example: 120/70
  Systolic/diastolic
  Turbulent/**laminar**

Systemic blood pressure

$$systemic\ blood\ pressure = \frac{systolic\ blood\ pressure}{diastolic\ blood\ pressure}$$

The blood pressure in the main arteries of your body that run from the left side of your heart to the rest of your body

- pleural sac forms double membrane surrounding the lungs (in-between lungs and rib cage)
- if the pleural cavity is opened to the atmosphere (e.g. puncture wound) air flows in and lungs collapse → PNEUMOTHORAX

Regulation of blood pH in humans

Homeostasis (pH blood = 7.4; tidal volume breathing)

↓

Stimulus e.g. increase in CO_2 in blood due to breathlessness (e.g. from stress)

↓

Increases HCO_3^- in blood → decrease in pH

↓

Chemoreceptors in heart detect a drop in pH

↓

Medulla oblongata in brain detects low pH in CSF and receives signals from chemoreceptors

↓

Sends signals to ribcage/diaphragm to increase depth and frequency of breathing

↓

Decreases CO_2 in blood, restoring homeostatic blood pH

Partial pressure of CO_2 and O_2 vary

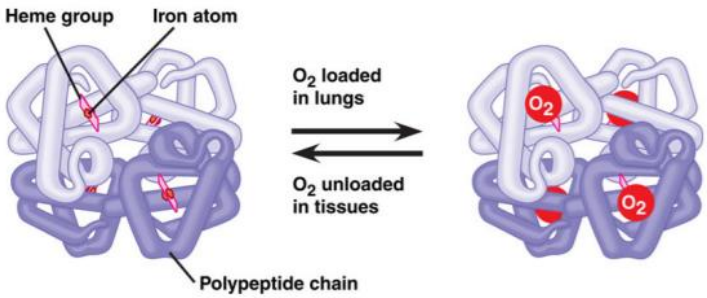
To regulate circulation and gas exchange

Area of the body	PP of O_2 (mmHg)	PP of CO_2 (mmHg)
Exhaled air	120	27
Inhaled air	160	0.2
Pulmonary veins & systemic arteries (oxygenated)	104	40
Alveolar spaces	104	40
Pulmonary arteries & systemic veins (deoxygenated)	40	45
Body tissues	<40	>45

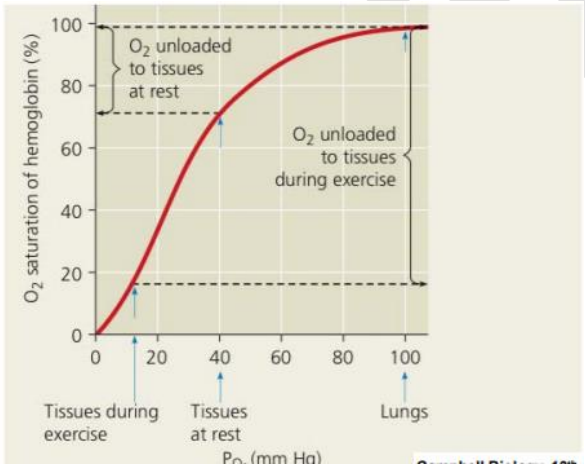
How does haemoglobin transport O_2?

Positive cooperativity

- when one O_2 binds to one heme group, there is a slight conformational change to all polypeptides
- makes it easier for O_2 to bind to haemoglobin



Haemoglobin dissociation curve



At rest, O2 is unloaded to tissue → it is essentially put away for a later time when it is needed e.g. for exercise

Bohr shift:

When pH decreases due to increased CO2, the haemoglobin dissociation curve shifts to the right

Graph explained:

- During exercise cardiac output and blood flow to muscle fibres increase.
- This increases cellular respiration, which uses O_2. Therefore exercise causes a drop in O_2 in tissue capillaries (from <40mmHg → to 10-15mmHg) and a decrease in saturation of O_2 in haemoglobin (especially due to positive cooperation in binding of O_2 to haemoglobin heme sites).
- The body responds by unloading O_2 to tissues.

MODULE 5 – PRINCIPLES OF ENDOCRINE FUNCTION

5 types of chemical signalling

- TSH stimulates endocrine cells in thyroid gland to secrete thyroid hormone (T_3 and T_4) into blood stream
- Thyroid hormone acts on target cells to restore normal bioenergetics
- Thyroid hormone blocks TRH release from hypothalamus & TSH release from anterior pituitary → prevents overproduction (negative feedback)

Homeostatic regulation of blood glucose

✓ Antagonistic hormone pair example

Insulin ↓blood glucose	Glucagon ↑blood glucose
• Stimulus: ↑blood glucose • **Beta cells** in pancreas release insulin into blood • **Insulin** enhances body cell uptake of glucose • Insulin stimulates the liver to store glucose as glycogen • **Insulin stimulates a cascade of phosphorylation**	• Stimulus: ↓blood glucose • **Alpha cells** in pancreas release glucagon into the blood • **Glucagon** promotes the breakdown of glycogen in the liver, releasing glucose into the blood • **Glucagon acts on GPCR and results in c-AMP production**

Pituitary gland hormones – GOATFLAPM

BLUE = anterior pituitary nontropic & tropic hormone
RED = posterior pituitary hormones tropic hormones
PURPLE = anterior pituitary tropic hormones
GREEN = anterior pituitary nontropic hormones

[ANTERIOR PITUITARY] nontropic and tropic hormone

Growth hormone (GH)

↑blood glucose by:

1. Acting on the liver to release insulin-like growth factors (IGFs) into the bloodstream, which directly stimulate bone and cartilage growth (TROPIC)
2. Directly breaking down fat and inducing tissue growth (NONTROPIC)

[POSTERIOR PITUITARY] hormones

Oxytocin

✓ Positive feedback loop example

- Stimulates contraction of smooth muscles in uterus and mammary glands
- POSITIVE FEEDBACK: response (milk release) causes stimulus to continue (suckling)

Anti-diuretic hormone (ADH)/ vasopressin

✓ Negative feedback loop example
↑retention of water via the kidneys ↓blood osmolarity

- Stimulus: ↑blood osmolarity e.g. sweating
- Osmoreceptors in the hypothalamus trigger the release of ADH from posterior pituitary
- ADH causes hypothalamus to generate thirst
- ADH also binds to surface receptors on collecting duct cells in the distal convoluted tubule of the kidney
- cAMP-mediated signalling pathway: protein kinase A puts more aquaporin water channels on the lumen side of the collecting duct cells → more fluid is retained instead of being flushed out in urine

[ANTERIOR PITUITARY] tropic hormones

TSH (thyroid-stimulating hormone/thyrotropin)

stimulates endocrine cells in thyroid gland to secrete thyroid hormone (T_3 and T_4) into blood stream

FSH and LH (gonadotropins – follicle-stimulating hormone, luteinizing hormone)

Stimulate the activities of male and female gonads e.g. estrogen production by ovaries

ACTH (adrenocorticotropic hormone)

Stimulates the production and secretion of steroid hormones (corticosteroids) by adrenal cortex (later in detail)

[ANTERIOR PITUITARY] nontropic hormones

Prolactin

Stimulates mammary gland growth and milk production in animals

MSH (melanocyte-stimulating hormone)

Hypothalamus connection to posterior vs anterior pituitary

- Neurons from the hypothalamus do not enter the anterior pituitary gland directly. Rather, hormones secreted from neurosecretory cells of the hypothalamus enter the anterior pituitary via a portal system: fenestrated blood vessels → rapid exchange.
- In contrast, hypothalamic neurons reach all the way to the posterior pituitary, releasing hormones locally via neurosecretory cells.

Diabetes insipidus – lack of ADH

Mutations that prevent ADH production, inactivate ADH receptor genes, or inactivate aquaporin genes. This leads to inefficient retention of water by the kidneys → solute imbalances and severe dehydration (dilute urine). Alcohol can also temporarily inhibit ADH release, resulting in similar symptoms.

Diabetes mellitus

Body's inability to properly regulate blood glucose levels

Type 1 = insulin-dependent

Autoimmune disorder in which immune system destroys pancreatic beta cells → lack of insulin release → poor uptake of glucose by body cells and poor glycogen storage of glucose by liver

Type 2 = non-insulin-dependent

Involves insulin deficiency or reduced response by target cells due to changes in insulin receptors

MODULE 6 – PLANT FORM AND FUNCTION

Photosynthesis

Photosynthesis	Used by autotrophs to convert light energy into chemical energy (organic good); occurs mainly in the leaves of plants
Autotrophs	(plants) organisms that are able to sustain themselves without eating other organisms or substances derived from other organisms
Heterotrophs	(animals) organisms that need to obtain organic substaces

2 mechanisms required for photosynthesis

1. Light reactions
2. Calvin cycle

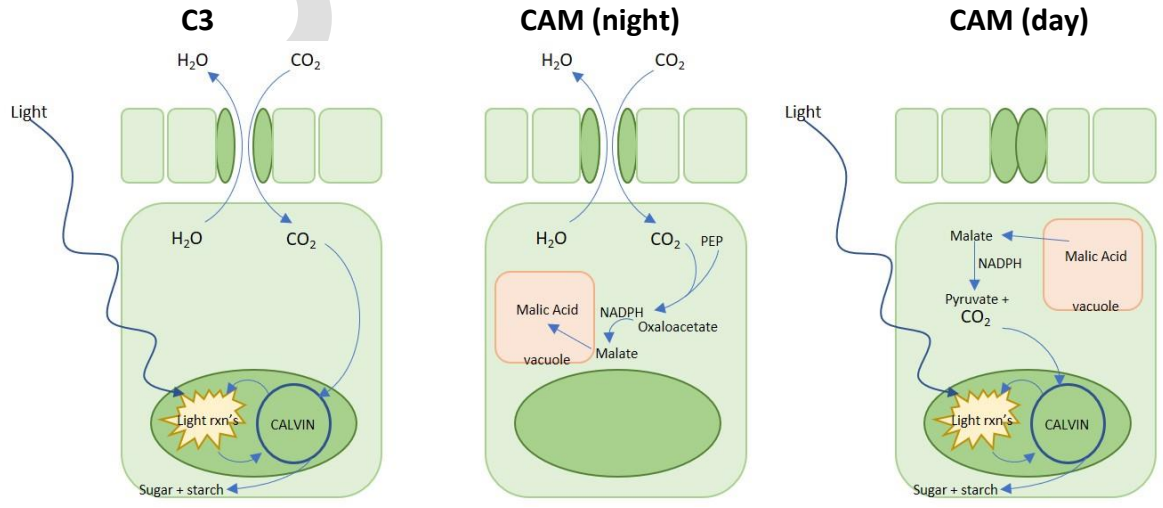
light reactions

- Convert light → to chemical energy
- Require chlorophylls (light absorbers)
  - Chlorophyll a: main photosynthetic pigment
  - Chlorophyll b: accessory pigment, which means it absorbs different wavelengths of light to chlorophyll a
  - Carotenoids: accessory pigments (yellow)
  - **Chlorophyll chemical structure** = porphyrin ring (light-absorbing head) and hydrocarbon tail (interacts with hydrophobic regions of proteins inside thylakoid membranes of chloroplast).
- **PHOTOSYSTEMS**
  - Centres for light reactions located within thylakoid membrane
  - PSII → PSI produces ATP and NADPH for use in Calvin cycle in stroma
  - ATP synthase facilitates passive diffusion of H+ products from PSII out to stroma (high to low)

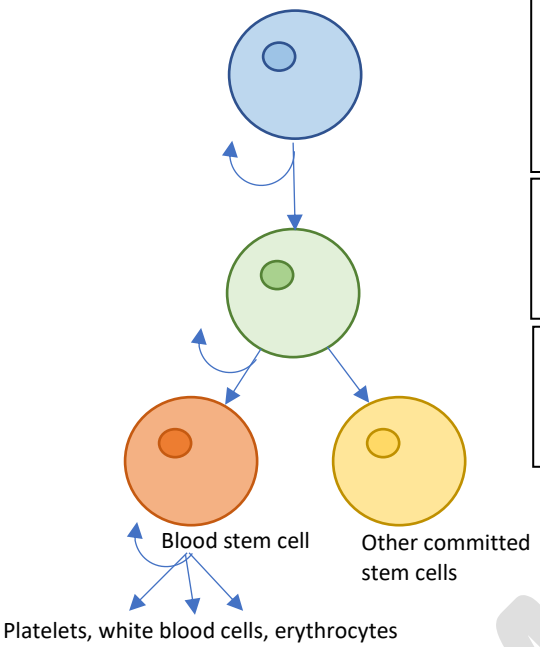
Calvin cycle

- Converts CO_2 → sugar (requires ATP and NADPH)
- 3 phases: carbon fixation (via RUBISCO) → REDUCTION → regeneration of CO_2 acceptor RuBP

CAM vs. C3 plants



- **Stem cells defined by two characteristics:**
    1. Self-renewal → make copies of themselves
    2. Differentiation → develop into more specialized cells
    3. Types of stem cells:



Totipotent stem cell
- Unlimited capability
- Can form extraembryonic membranes and tissues (umbilical cord and placenta), the embryo, and all postembryonic tissue and organs
- E.g. an embryo

Pluripotent stem cell
- Can give rise to most, but not all, tissues of an organism
- E.g. inner mass cells, e.g. embryonic

Multipotent stem cell
- Cells that are committed to give rise to cells that have a specific function
- E.g. blood cells

Embryogenesis

- The fimbriae of the uterus surround the ovary. Inside the ovaries are stem cells differentiating to become egg cells
- Ampulla is negative pressure, sucking on the egg so that the egg can travel down the fallopian tubes
- After fertilisation event, totipotent stem cells are dividing in the uterus (morula) → 24-hour long cell divisions. They give rise to blastocyst which forms the inner cell mass to form the embryo.
- When the blastocyst (early embryo) reaches the uterine cavity, the cavity lowers its pH, hatching the blastocyst (breaking away the outer gelatine wall). Once the hatched blastocyst attaches and burrows into the wall of the uterine cavity then you are pregnant (6 days after eggs is fertilisation)
- Blastocyst = inner cell mass and trophectoderm

WHERE DO WE GET STEM CELLS FROM?

Embryonic stem cells (ESC)

- In vivo fertilized eggs → 8 cell embryo → blastocyst → cultured undifferentiated stem cells (pluripotent), which were sucked out using a micropipette → neural cells, cardiac muscle, blood cells etc. differentiated by using drugs/hormones on the culture.
- Donated from IVF couples
- Immortal cell that propagates indefinitely. Has the potential to differentiate into a cell of any germ layer = pluripotent

END OF SAMPLE

Full document is 50 pages

Includes all course content

(lectures + practicals + PASS)

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