Chapter 1: Cells

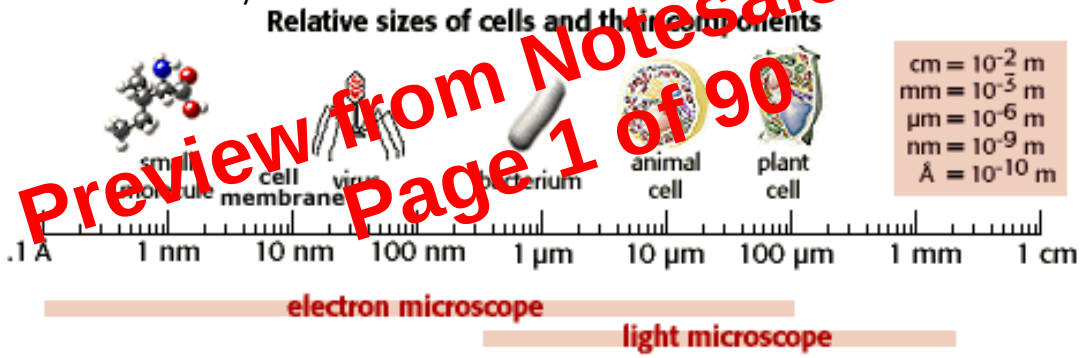
1.1 Cell Theory

- The Cell Theory:
  - All living organisms are composed of one or more cells
  - Cells are the smallest, most basic units of structure and function
  - Cells can only come from existing cells

- Evidence for the Cell Theory;
  - When living organisms are observed under microscopes they always appear to be composed of cells
  - The cell is the smallest unit of structure and function that can show all characteristics of living processes
  - Cells carry out replication to form new cells

- Unicellular organisms carry out all the functions of life
  - Metabolism
  - Response
  - Homeostasis
  - Growth
  - Reproduction
  - Nutrition

- Cell Diversity:



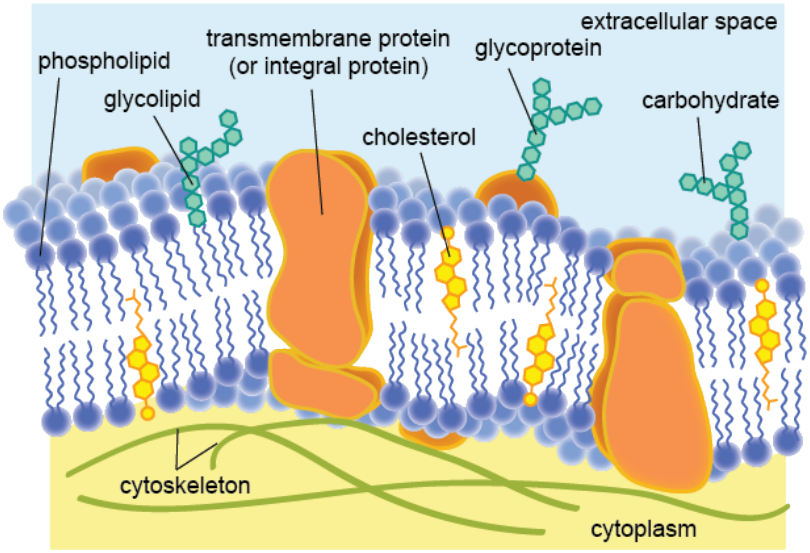
- $Magnification = \frac{size\ of\ image}{size\ of\ specimen}$

- Surface Area to Volume Ratio:
  - Functions of volume include:
    - Rate of heat production
    - Waste production
    - Resource consumption
  - Functions of surface area include:
    - Rate of exchange of materials and energy (heat)
  - The rate of exchange of substances depends on the organism's surface area that is in contact with the surroundings
  - As size increases surface area : volume ratio decreases
    - If the ratio decreases, the rate of exchange decreases
  - This rule is a limiting factor of cell size

Plant	Animal
Have chloroplasts	No chloroplasts
Have chlorophyll	No chlorophyll
Have a cell wall	No cell wall (just cell membrane)
Have large vacuoles	Have small or no vacuoles
Don't have mitochondria	Mitochondria present
Both are eukaryotic cells	

- Roles of extracellular components
  - Plant cell wall
    - Composed of cellulose
    - Maintains cell shape
    - Prevents excessive water uptake
    - Prevents excessive water uptake
    - Holds the whole plant up against gravity
  - Animal extracellular matrix (cell membrane)
    - Surrounds the tissues of liver ducts
    - Provides structural support for integrity of tissues or organs
    - Support
    - Adhesion
    - Movement

1.4 Cell Membranes



- Hydrophobic and hydrophilic properties of phospholipids help to maintain the structure of cell membranes
  - The phosphate group = hydrophilic (polar)
    - Suited to the large water content of the tissue fluid and cytoplasm on opposite sides of the membrane
  - The fatty acid tails are non changed = hydrophobic
    - Creates a barrier between internal and external water environments of the cell
    - The tails create a barrier to the movement of charged molecules

- Functions of membrane proteins
  - Hormone binding sites
  - Immobilized enzymes
  - Cell adhesion
  - Cell-to-cell communication
  - Channels for passive transport
  - Pumps for active transport

- Diffusion: movement of molecules from an area of high concentration to an area of lower concentration down a concentration gradient
- Osmosis: movement of water molecules from an area of high concentration to an area of lower concentration down a concentration gradient

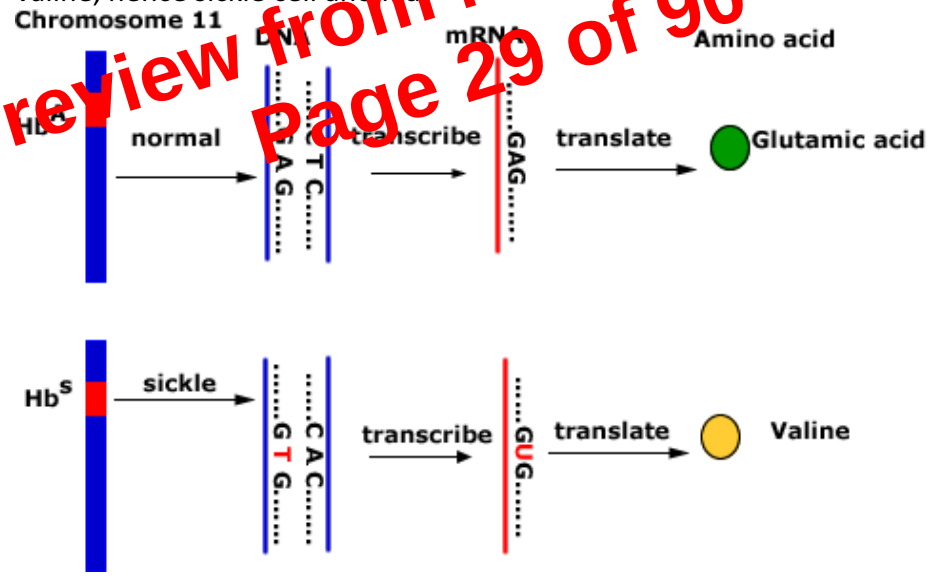
- Passive transport (no expenditure of energy)
  - Molecules have kinetic energy
  - The membrane allows them to pass through without any additional energy to the kinetic energy they already have
  - They will pass in both directions (in/out) but always down a concentration gradient
  - Simple diffusion

Chapter 4: Genetics

4.1 Chromosomes, Genes, Alleles, Mutations

- Eukaryotic chromosomes are made of DNA and proteins called histones
- Gene – a heritable factor that controls a specific characteristic
- Allele – a specific form of a gene, differing from other alleles by one or a few bases only, and occupying the same gene locus as other alleles for the gene
- Genome – the whole of the genetic information of an organism
- Gene mutation
    - Consists of large scale changes in chromosomes
    - It results in chromosomal abnormalities
        - E.g. A change in sequence of an allele
        - The changed base sequence may produce a different amino acid sequence in the transplanted protein
            - This may not happen because of the degenerate nature of the genetic code
    - The expression of the mutated gene may or may not be beneficial to the organism
    - Substances that cause mutations are called mutagens (chemicals, radiations)

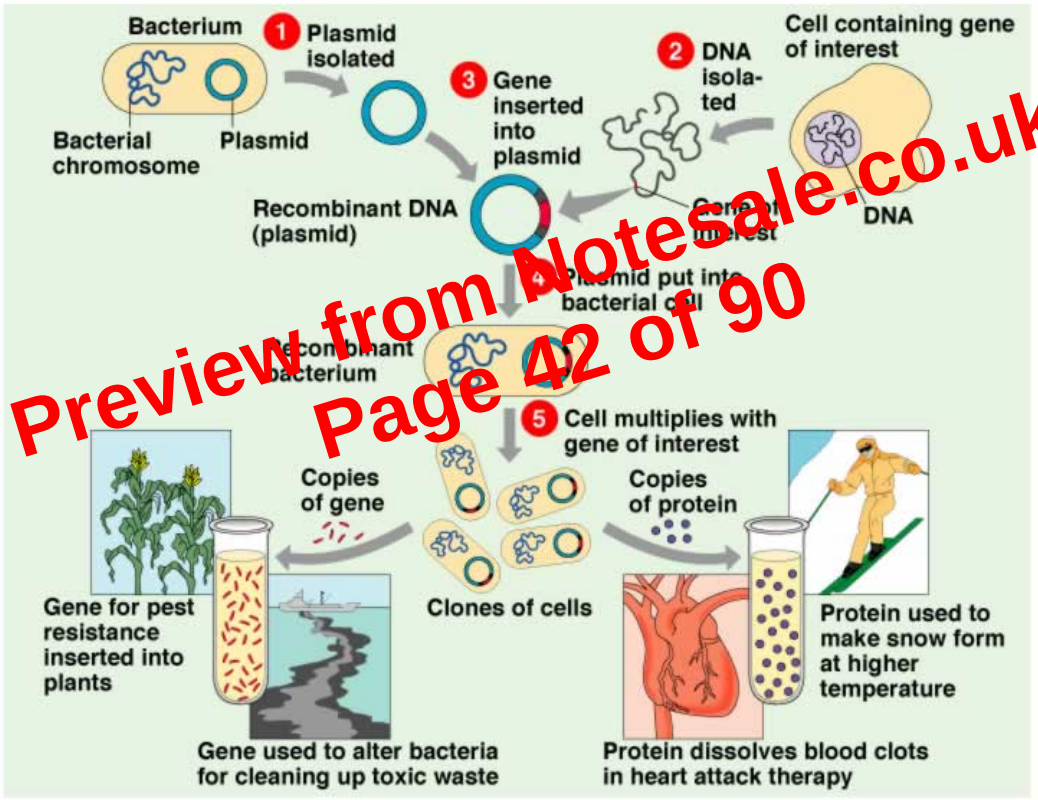
- Sickle cell anemia results from the substitution of a single base, resulting in the exchange of a single amino acid in the polypeptide, in the gene coding for one of the subunits of hemoglobin
- The codon GAG is muted into GTG causing glutamic acid to be replaced by valine, hence sickle cell anemia



- Production of gene probes to detect sufferers and carries of genetic disease
- Lead to production of new drugs base on DNA sequences and the genes for which they code

- When genes are transferred between species, the amino acid sequence of polypeptides translated from them is unchanged because the genetic code is **universal**

- Gene transfer
  - Plasmids of E.coli (small circles of DNA) can be removed and cleaved by restriction enzymes at specific sequences
  - DNA fragments from another organism can also be cleaved by the same restriction enzyme and these pieces can be added to the open plasmid and spliced together by DNA ligase
  - The recombinant plasmids formed can be inserted into new host cells and cloned



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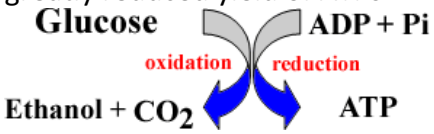
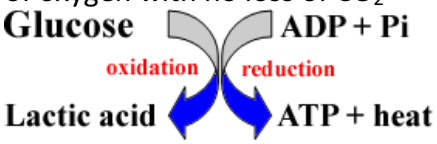
- GM (genetically modified) crops or animals
  - Tomato salt tolerance
    - Tomato plants have been modified to carry the gene for salt tolerance
    - The origin of the gene was a weed called: Arabidopsis thaliana
    - This now provides the opportunity for a crop to be grown in otherwise sterile soil

Chapter 6: Cell Respiration & Photosynthesis

- Cell respiration – the controlled release of energy from organic compounds to make ATP
- Pyruvate – 3 carbon molecule
- In cell respiration, glucose in the cytoplasm is broken down by glycolysis into pyruvate with a small yield of ATP
- Anaerobic YEAST respiration
    - Pyruvate is converted into ethanol with the release of CO_2 and a greatly reduced yield of ATPs

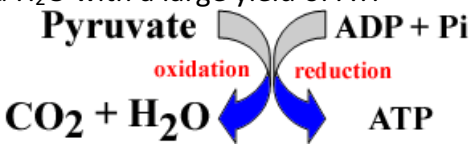


- Anaerobic HUMAN respiration
    - In human cells, the pyruvate is converted into lactate in the absence of oxygen with no loss of CO_2



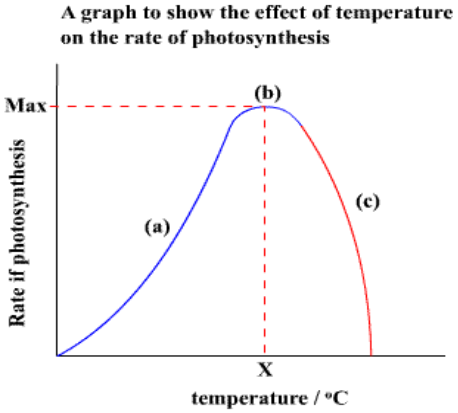
    - Anaerobic cell respiration is a means for cells to regenerate NAD^+ from NADH
    - Without oxygen present, most cells can only make ATP through reactions of glycolysis
    - During glycolysis, NAD^+ is reduced to NADH
    - In the presence of oxygen, NADH produced in this way will be oxidized back to NAD^+ that can take part in more reactions of glycolysis
    - Without oxygen, cells use different pathways to regenerate NAD^+ from NADH

- In aerobic cell respiration, pyruvate is broken down in the mitochondrion into CO_2 and H_2O with a large yield of ATP



    - In aerobic respiration, pyruvate is oxidized further in the mitochondria, where a lot of ATP is produced
    - For this to occur, oxygen is required. This is transported to the cell on the hemoglobin found inside red blood cells
    - CO_2 is produced as a waste and diffuses into the blood where its transported to the lungs and excreted in exhaled air.

Photosynthesis



- Photosynthesis involves the conversion of light energy into chemical energy
- White light from the sun is composed of a range of wavelengths (colors)
- Chlorophyll is the main photosynthetic pigment
- Pigments actively absorb certain colors of light due to their molecular structure
    - The remaining colors of light are reflected and give rise to the colors we see.
    - Chlorophyll mainly absorbs red and blue and reflects green
- Light energy is used to split water molecules (photolysis) to give oxygen and hydrogen, and to produce ATP
- ATP and hydrogen (derived from the photolysis of water) are used to fix CO_2 to make organic molecules
- The rate of photosynthesis can be measured directly by the production of O_2 or the uptake of CO_2, or indirectly by the increase in biomass

Effects of Temperature on rate of photosynthesis

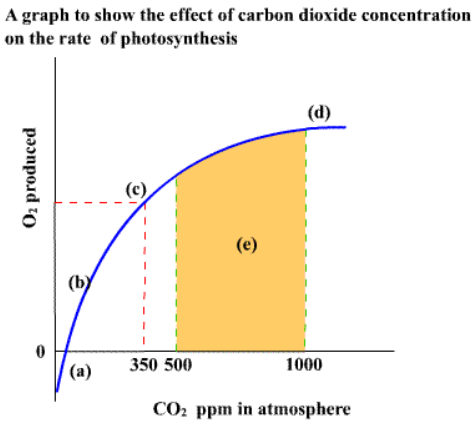
(a) Increasing rate of photosynthesis as the kinetic energy of reactants increases.
(b) Maximum rate of reaction of photosynthesis at the 'optimal' temperature.
(c) Decrease in rate of photosynthesis as the enzymes become unstable and denature.

Photosynthesis is a biological reaction and like all other such reactions there are steps that require the presence of enzymes.

Temperature as we have already met is a change in the average kinetic energy of the particles.

The effects of Carbon Dioxide concentration

Carbon dioxide is one of the reactants of the reaction so this graph is very much like the effect of substrate on the rate of reaction.



(a) O_2 is used up as the plant is not photosynthesising but only respiring.
(b) As the concentration of the carbon dioxide (substrate) increases the rate of reaction increases.
(c) The atmospheric levels of carbon dioxide and the associate rate photosynthesis.
(d) Maximum rate of photosynthesis (see section e).
(e) The is a range of values for different plants reaching their saturation level with carbon dioxide. One the saturation level has been reached there is no further increase in the rate of photosynthesis.

The Role of NADH + H^+

- As the cycle progresses, hydrogen atoms are removed
- These contain high energy electrons from the original food molecule (often glucose) and are collected by hydrogen carrying coenzymes (NAD^+ and FAD^+)

3. The Electron Transport Chain

- NADH + H^+ and $FADH_2$ coenzymes are made in the Kreb's cycle and enter the ETC
- The ETC provides the means of generating ATP from the energy in the hydrogen atoms carried by these reduced compounds
- Oxygen is required

Oxidative Phosphorylation in terms of **chemiosmosis**

- Chemiosmotic theory - the synthesis of ATP is coupled to electron transport and the movement of protons (H^+ ions)
- The electron transport carries are strategically arranged over the inner membrane of the mitochondrion
- As they oxidize NADH + H^+ and $FADH_2$, energy from this process forces protons to move, against the concentration gradient, from mitochondrial matrix to the space between the two membranes (using proton pumps)
- Eventually, the H^+ ions flow back into the matrix through channels in the **ATP synthetase** enzyme complexes embedded in the membrane
- As ions flow through the enzymes down their concentration gradient, energy is released that powers the endergonic reaction producing ATP from ADP + P

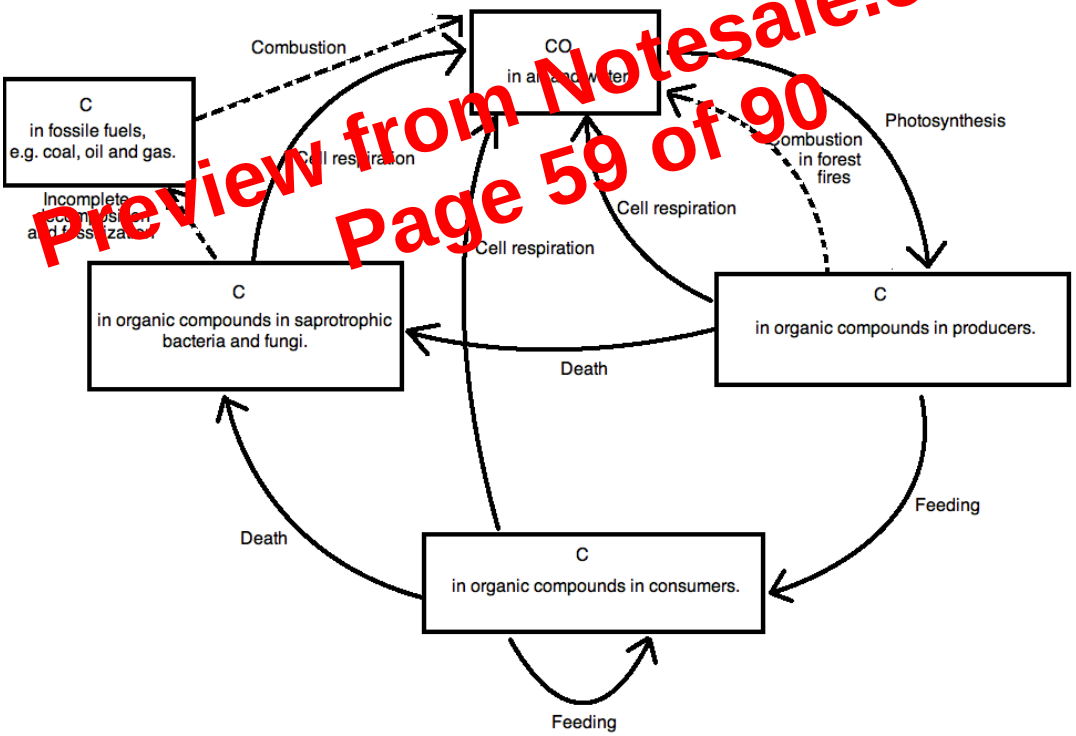
➢ Chemiosmosis
  - Needed for aerobic (but not anaerobic) respiration
  - Used in oxidative phosphorylation
    - Oxygen accepts electrons at the end of ETC
    - Also accepts protons to form water (using oxygen)
    - Allows more electrons along ETC
    - Allows reduced NAD (NADH) to be oxidized (regenerated)
    - Allows the Krebs cycle to continue
    - Allows ATP production
    - Allows higher yield of ATP from glucose in respiration (32-38 instead of 2)
- **Mitochondrion – Structure/Function Relationship**
  - Cristae forms larger surface area for the electron transport chain
  - The small space between the inner and outer membranes is for accumulation of protons
  - The fluid matrix contains enzymes of the Krebs cycle
- The structure of mitochondrion allows for a large proton gradient to be formed
  - Gradient is generated by/across the inner mitochondrial membrane
  - Cristae exist so the inner membrane has a larger surface area
  - Protons are stored between inner & outer membranes / within double membrane

- Released energy lost as heat
- Not all food is digested/energy lost in feces
- Not all organisms in a trophic level are eaten by the next (many die before being eaten)
- Energy of dead is lost to decomposers and Saprotrophs in other food chains

- Energy enters and leaves ecosystems but nutrients must be recycled
  - Ecosystems can afford to use up energy because the sun provides a constant supply of new energy that can be utilized by organisms
  - Nutrients must be recycled because there is a limited supply on the plant; and so the same N atoms or water molecules have been used over and over again by countless generations of organisms

- Saprotrophic bacteria and fungi recycle nutrients
  - Decomposers feed on the wastes and dead remains of organisms
  - Without them, an ecosystem would quickly run out of nutrients such as C and N as the corpses piled up
  - Decomposers return carbon to the environment in the form of carbon dioxide produced by respiration
  - Nitrogen is returned to the environment as amino acids are broken down and ammonia produced by extracellular digestion and/or excretion
  - Other inorganic substances (such as P, Ca, Fe, and Mg) are returned to the environment in a similar way as the decomposers break down virtually all the complex organic molecules not consumed by traditional consumers and excrete anything they cannot use themselves.

7.2 The Greenhouse Effect



- Major gases studied in terms of trends as indicators of potential climate change
  - The gases studied include CO_2, methane and oxides of nitrogen
  - Atmospheric CO_2 has been monitored at the atmospheric laboratory in Hawaii since

	• The mechanical action of the stomach (churning) also promotes digestion by mixing the food • Food → chyme
Small intestine	• Nutrients are absorbed into bloodstream • Pancreas + gallbladder secrete substances in it to aid digestion • Lined with smooth muscle to allow for the mixing and moving of digested food products (segmentation + peristalsis) • Contains small pits that secrete intestinal juices • Contains villi that increase surface area to volume ratio to optimize rate of absorption
Large intestine	• Absorbs water and dissolved minerals • Converts remains from a fluid state into semi solid feces • Feces are stored in rectum and eliminated out of the anus

- Structure/function of villi

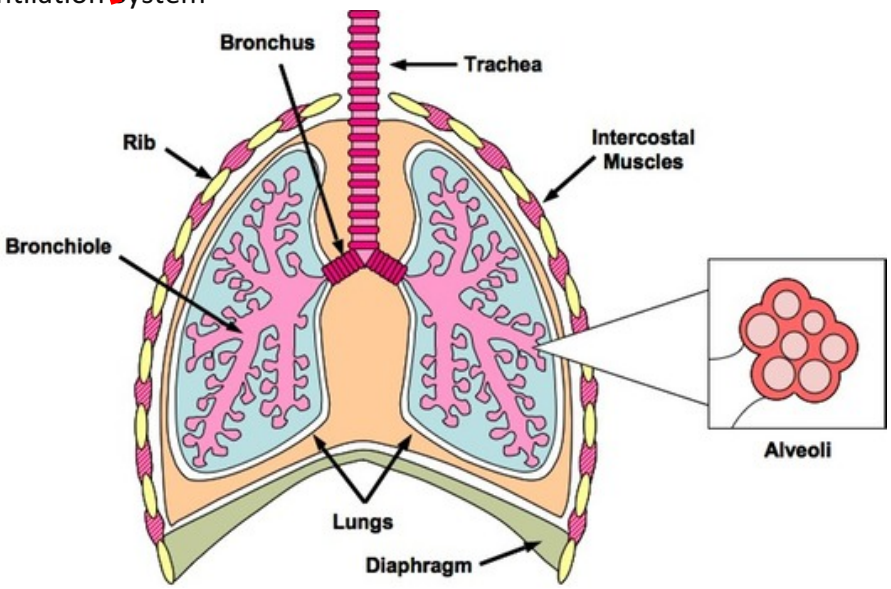
Structure	**Function**
Microvilli	Increase surface area allowing greater rate of absorption
Rich capillary network	Help maintain concentration gradient for absorption by transporting absorbed products away
Single epithelial layer	Ensures minimal diffusion distance between the intestinal lumen and capillary network
Lacteals	Absorb lipids from intestine into lymphatic system
Intestinal crypts	Located between villi, release juices that act as carrier fluids for nutrients
Membrane proteins/mitochondria	Enable active transport

Gas Exchange

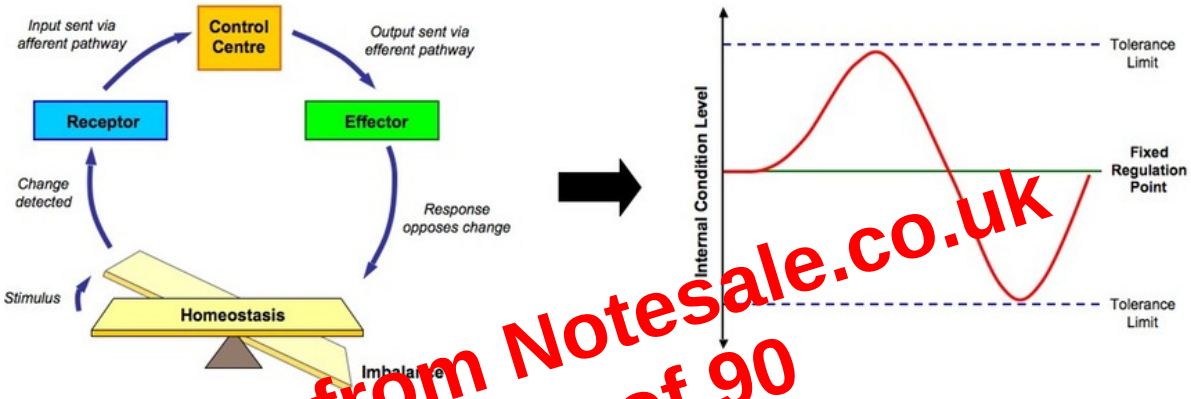
- Ventilation – gas exchange between the lungs and the atmosphere (physical act of breathing)
- Gas exchange – exchange of oxygen and carbon dioxide in alveoli and the blood stream
- Cell respiration – release of ATP from organic molecules (enhanced by presence of oxygen)
- The ventilation system
    - Gas exchange = passive so ventilation system needs to maintain a concentration gradient within the alveoli
    - Oxygen is needed by cells to make ATP, CO_2 = waste product, must be removed
    - Oxygen must diffuse in while CO_2 must diffuse out
    - Requires high concentration of oxygen + low concentration of CO_2
    - Concentration gradient is maintained by continually cycling the air in the lungs with the atmosphere
- Alveoli

Structure	Function
Thin wall	Made of a single layer of flattened cells so diffusion distance is small
Rich capillary network	Alveoli covered by a dense network of capillaries that help to maintain a concentration gradient
Increased SA:Vol ratio	High numbers of spherically shaped alveoli optimize SA for gas exchange
Moist	Cells in the lining secret fluid to allow gases to dissolve and to prevent alveoli from collapsing

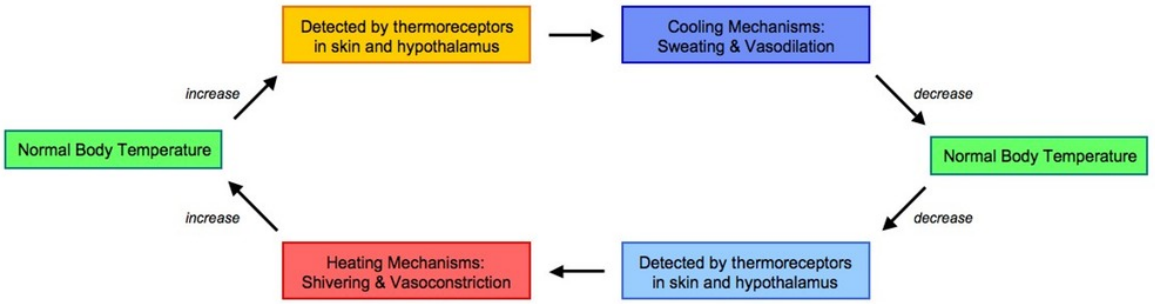
- Human Ventilation System



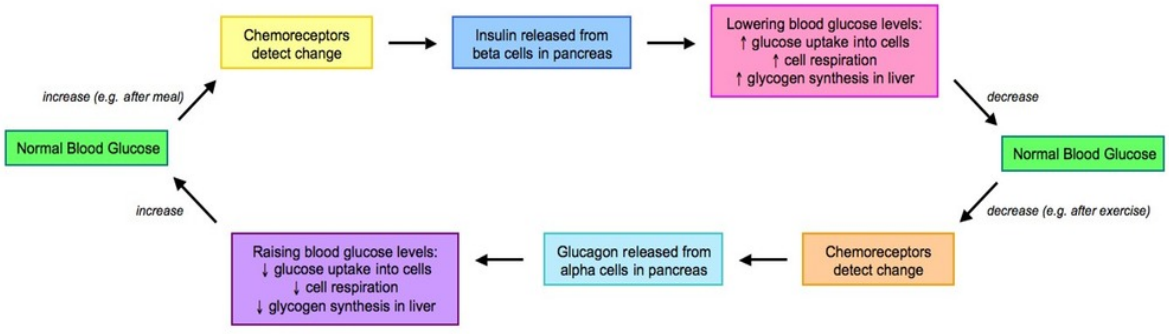
- The endocrine system consists of glands that release hormones that are transported in the blood
- Homeostasis involves maintaining the internal environment between limits including blood pH, CO_2 concentration, blood glucose concentration, body temperature and water balance
- Homeostasis involves monitoring levels monitoring levels of variables and correcting changes in levels by –'ve feedback mechanisms
    - Most homeostatic control mechanisms operate through a –'ve feedback loop
    - When specialized receptors detect a change in internal condition, the response generated will be the opposite of the change that occurred
    - When levels returned to equilibrium the effector ceases to generate a response
    - If levels go too far in the opposite direction antagonist pathways will be activated to restore the internal balance



- Control of body temperature
    - Animals capable of temperature regulation within a given range are called homoeothermic



- Control of blood glucose concentration

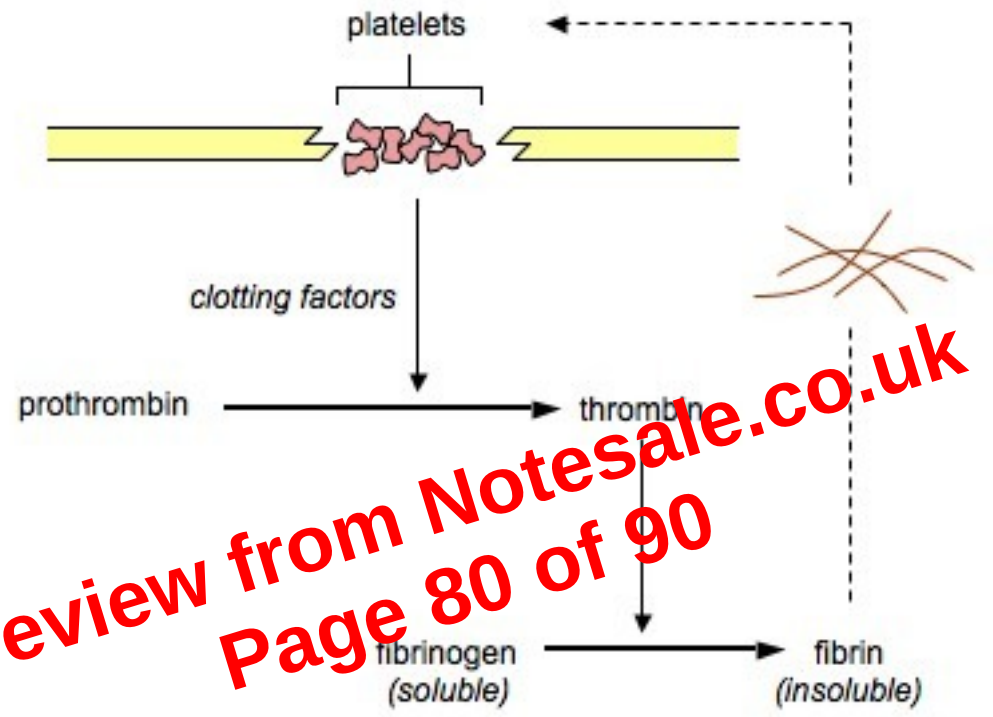


Type I Diabetes	Type II
Insulin-Dependent Diabetes Mellitus (IDDM)	Non Insulin-Dependent Diabetes Mellitus (NIDDM)
Usually occurs during childhood (early onset)	Usually occurs in adulthood (late onset)
Body does not produce sufficient insulin	Body does not respond to insulin
Caused by destruction of beta cells (autoimmune?)	Caused by down-regulation of insulin receptors (diet?)
Requires insulin injections to regulate glucose levels	Can be controlled with a carefully monitored diet

Topic 11: Health and Physiology (HL)

Defense against Infectious Disease

- Blood clotting



  - Clotting prevents loss of blood from broken vessels
  - Damaged cells and platelets release chemical signals called clotting factors that trigger coagulation
  - These convert prothrombin into the enzyme thrombin
  - Thrombin catalyzes the conversion of the soluble plasma protein fibrinogen into an insoluble form fibrin
  - Fibrin forms insoluble mesh of fibers = trap blood
  - Clotting factors also cause platelets to become sticky
- Challenge & Response
  - When the body is challenged by a foreign pathogen it will respond with both a non-specific and specific immune reaction
  - The body is capable of recognizing invaders as they do not possess the molecular markers that designated all body cells as self (MHC class I)
  - Non specific immune cells (macrophages) present foreign antigens to lymphocytes as example of non-self (MCH class II)
  - These lymphocytes can then respond to the production of antibodies to destroy the foreign invaders

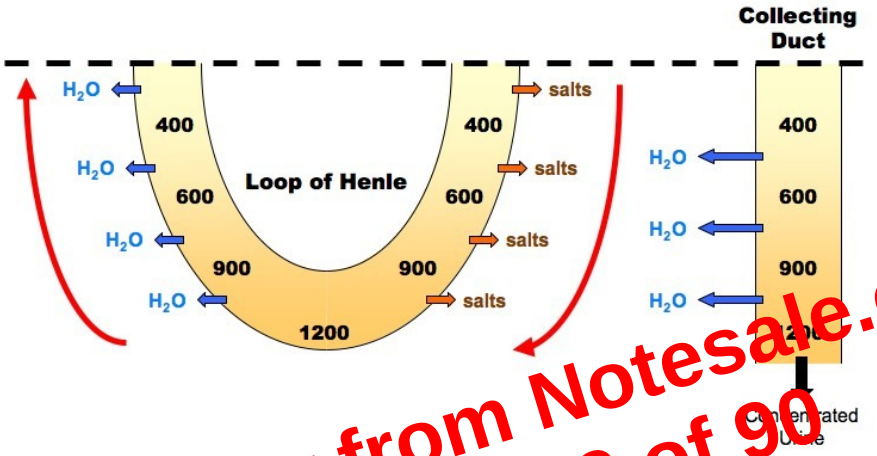
    - An antibody specific to hCG is made and tagged to an indicator molecule
    - When hCG is present in the urine it binds to the anti-hCG monoclonal antibody and this complex will move with the fluid until it reaches a second group of fixed antibodies
    - When the complex binds to the fixed antibodies, they will appear as a blue line due to the presence of indicator
- Treatment use:
    - Used for emergency treatment of rabies by injecting purified quantities of antibody
- Vaccination
    - Induce artificial active immunity by stimulating the production of memory cells
    - A vaccine contains weakened or attenuated forms of pathogen and is injected in bloodstream
    - Because a modified form of pathogen is infected, the individual should not develop disease symptoms
    - The body responds by initiating a primary response, resulting in the production of memory cells
    - When exposed to the actual pathogen, the memory cells trigger a secondary immune response that is much faster and stronger
    - Vaccines confer long-term immunity, however because memory cells may not survive a life time, booster shots may be required

Benefits	**Dangers**
Vaccinations result in active immunity	May produce symptoms of disease on vaccinated individuals
Limit the spread of infectious disease	May be human error in preparation, storage or administration
Disease may be eradicated entirely	Individuals may react badly to vaccines
Vaccination programs may reduce mortality rate and protect vulnerable groups	Immunity may not be life long
Vaccination will decrease crippling effect of disease	There may be toxic effect of mercury based preservatives used in vaccines
Decrease health care cost associated with treating disease conditions	

Muscles and Movement

- Bones – provide hard framework stability and act as levers to facilitate movement
- Ligaments – hold bones togethers
- Muscles – provide the force required for movement by moving one bone in relation to another
- Tendons – connect muscles to bones
- Nerves – motor neurons provide the stimulus for muscle movement and coordinates sets of antagonistic muscles

- Osmoregulation
  - As collecting duct passes through the medulla as it drains into the ureter, the hypertonic solution of the deep medulla will draw water by osmosis
  - ADH = release by posterior pituitary in response to dehydration
    - Increases permeability of collecting duct to water allowing more water to be reabsorbed via production of aquaporins
    - = less water in the filtrate and urine = more concentrated
    - when individual is suitably rehydrated, ADH levels will decrease and less water will be reabsorbed from the collecting ducts



- Differences in concentration

Proteins	Glucose	Urea
Present in blood plasma but not in glomerular filtrate or urine b/c proteins cannot pass across the basement membrane during ultrafiltration	Present in blood plasma and glomerular filtrate but not in urine (normally) b/c glucose is selectively reabsorbed by active transport	Will be present in blood plasma, glomerular filtrate and urine Only about 50% of urea is reabsorbed (normally to help regular the medullary osmolarity) Urea becomes more concentrated as water is reabsorbed Concentration of urea depends on concentration of water in urine