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Updated to 2016-18 Syllabus

# CIE A2-LEVEL BIOLOGY 9700

SUMMARIZED NOTES ON THE SYLLABUS

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# 1. BIODIVERSITY

## 1.1 Terms

- **Species:** is a group of organisms with similar morphological and physiological features, which can interbreed to produce fertile offspring and are reproductively isolated from other species.
- **Ecosystem:** is a relatively self-contained, interacting community of organisms, and the environment in which they live and with which they interact.
- **Niche:** is the role of an organism in an ecosystem (it is how an organism fits into the ecosystem).

## 1.2 Biodiversity

**Biodiversity:** The variety of species in an area along with their variation **within** species and the genetic diversity **between** them.

The three levels of diversity:

- Variation of ecosystems and habitats
- Number of different species in the ecosystem and their relative abundance
- Genetic variation within species
- Uses of maintaining biodiversity:
  - Maintains stability of ecosystem; preventing extinction
  - Maintains large gene pool (genetic variation)
  - Ecosystems provide 'services' for humans
  - Species can be source of new medicines
  - Resource such as food and wood
  - Leisure for humans to see in zoos; ecotourism
  - Climate stability

## 1.3 Genetic Diversity

- Is the diversity of the alleles within the genes in the genome of a single species
- A species can all have the same genes, but different alleles for those genes. Genetic diversity is assessed by finding proportion of genes with different alleles and how many alleles there are per gene.

## 1.4 Species Diversity

- The number of species in a community is known as species richness
- Species diversity, takes species richness into account, but also includes evenness of abundance of each species

In species diversity there are two points that need to be found and they are ***distribution*** and ***abundance***.

To do this we use means of **Random** sampling such as:

- Quadrat
- Mark and release
- Simpson's index

The importance of random sampling is that a habitat may be too large and too great for actual counting so a sample is quick and gives a representation of the whole habitat.

## 1.5 Random Sampling

**Quadrat sampling:**

- Marks of a specific area
- Take measurement of abundance of specific species
- Usually used with species that are stationary
- Samples are taken randomly to avoid any bias and increase accuracy of estimate
- 2 ways to use your results:
  - Species frequency: is the measure of the chance of a particular species being found in any one quadrant.

$$\frac{No.\ of\ Apperance}{No.of\ Quadrats} \times 100$$

  - Species density: is a measure of how many individuals there are per unit area.

$$\frac{Total\ No.\ of\ Calculated}{Total\ Area\ of\ All\ Quadrats}$$ Units: $m^{-2}$

A method was created due to it being difficult weather to measure a plant as a whole or as not at all from its percentage cover, this is the Braun-Blanquet scale.

| Braun-Blanquet scale | Range of cover (%) |
|---|---|
| 5 | 75-100 |
| 4 | 50-75 |
| 3 | 25-50 |
| 2 | 5-25 |
| 1 | <5; numerous individuals |
| + | <5; few individuals |
| r | solitary, with small cover |

**Mark-release and recapture:**

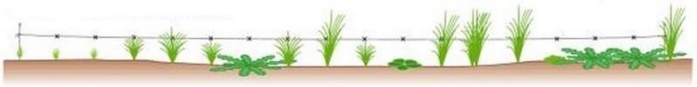
- Used with mobile animals
  - As many individuals possible are caught
  - Each individual is marked in a way that would not affect its chance of survival or reproduction
  - The marked individuals are counted and returned back to their habitat to mix randomly
  - After enough time elapses for mixing to take place, capture another sample
  - Number of marked and unmarked counted and used to calculate estimate of population

$$\frac{No.of\ 1st\ sample\ (marked) \times No.of\ 2nd\ Sample\ (total)}{No.\ Marked\ in\ Second\ Sample}$$

## 1.6 Systematic Sampling

- Used in areas where conditions such as altitude, soil moisture content, pH or exposure to light intensity varies
- 2 types of sampling:
- Line transect

  The number of organisms found at regular points along a line are noted

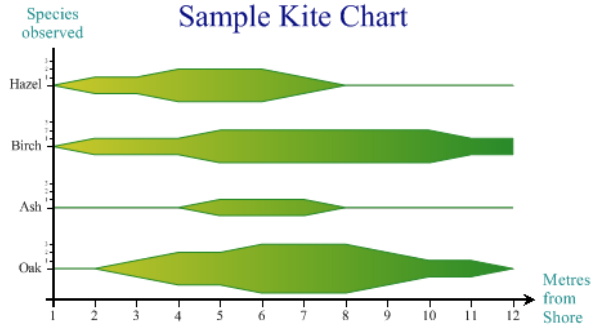


- Belt transect

  The abundance of organisms within quadrats placed at regular intervals

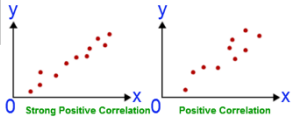
**Drawing a kite diagram**

- Find the highest value from the table e.g. 6 in this case
- Give each species 6 spaces
- Draw a straight line of 0 through the middle
- Divide the number you are plotting by two, plot it above and below the line (from 0)

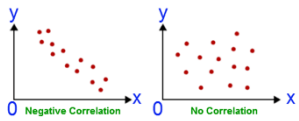



## 1.7 Correlation

**Pearson's correlation coefficient**




- Data must be distributed normally
- You can see this if the graph does not appear skewed or has obvious outliers




- Must have linear correlation
- Two variables does not matter which on x/y axis
- Quantitate data as measurements or counts

$$r = \frac{\Sigma xy - \bar{x}\bar{y}}{ns_x s_y}$$

The value of r is always between -1 and 1

**Spearman's rank correlation**

- Used when data not normally distributed

$$r_s = 1 - \left(\frac{6 \times \Sigma D^2}{n^3 - n}\right)$$

- The closer the value is to 1 the more likely it is that there is a correlation between the two sets of data
- The $r_s$ value you calculated is then compared with the critical value, if $r_s$ is greater, then null hypothesis is rejected, meaning there is a correlation.

## 1.8 Simpson's Index of Diversity

- After abundance of species is calculated in the area you are studying, use this formula will calculate the diversity

$$D = 1 - \left(\frac{n}{N}\right)^2$$

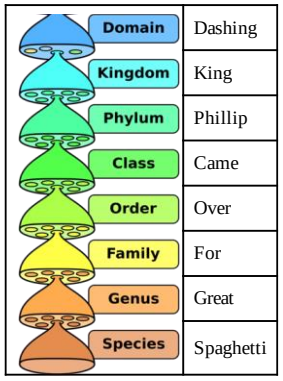
where n is the total number of organisms of a particular species, and N is the number of all species

- Value of D ranges from 0 to 1(1 being highly diverse)
- Advantage: do not have to identify organisms to calculate diversity

| Species | Number of individuals ,n | $\left(\frac{n}{N}\right)^2$ |
|---|---|---|
| | Shore A | |
| A | 24 | 0.00 |
| B | 367 | 0.110 |
| C | 192 | 0.030 |
| D | 14 | 0.000 |
| E | 83 | 0.006 |
| F | 112 | 0.010 |
| G | 207 | 0.035 |
| H | 108 | 0.010 |
| Total no. of individuals, N | 1107 | $\Sigma\left(\frac{n}{N}\right)^2 = 0.201$ |
| $D = 1 - 0.201 = 0.799 \therefore$ high diversity | | |

# 2. Classification

## 2.1 Taxonomic Hierarchy




- Biologists created a process called classification to arrange organisms into groups, as:
  - Difficult to memorize & absorb info. of each species separately
  - Taxonomy is the study &practice of classification, which involves placing organisms in a series of taxonomic units.
  - These taxa form a hierarchy which helps to group in order to become more specific.

## 2.2 Domain

Three domains:

| Feature | Bacteria | Archaea | Eucarya |
|---|---|---|---|
| Nucleus | No nucleus , no histone, but has strands of DNA and small circular Plasmids | No nucleus , has histone, but has strands of DNA and small circular Plasmids | Present, with DNA arranged as linear chromosomes with histone proteins |
| Membrane bound organelle | No membrane bound organelle | | Present |
| Ribosomes | 70S ribosomes | 70S ribosomes but have features that are similar to eukaryotic | 80S ribosomes in the sytosol, but also has 70S in mito/chloro |
| Cell division | Binary fission | | Mitosis |
| Cell wall | Always present and contains peptidoglycan | Cell wall present, but no peptidoglycan | Present sometimes (cellulose) and has cell membrane |
| Size | Usually single cell or small groups of cells | | Many forms: unicellular , colonial(group mutual benefit) and multicellular |
| | Archaea's metabolism is similar to that of bacteria, but the way transcription occurs much in common with eukarya | | |

## 2.3 Kingdoms

| Protoctista | Fungi | Plantae | Animalia |
|---|---|---|---|
| Eukaryotic | Eukaryotic | Multicellular, differentiated to form tissues and organs | |
| Single cell, or exist as group of similar cells | Do not have chlorophyll so cannot photosynthesize | Specialized cells | |
| Some animal like cells (no cell wall) → Protozoans | Heterotrophic nutrition- feed as parasites and getting organic compounds from other organisms | Autotrophic- Some have chloroplast and photosynthesize | Heterotrophic nutrition- rely on others to make their food or get their energy |
| Plant like (cellulose cell walls and chloroplast) algae | Reproduce by means of spores | Cells have large permanent vacuoles | Cell vacuoles are small and temporary like lysosomes and food vacuoles. |
| | Cell wall made up of chitin or other substances | Cell walls always present and made up of cellulose | No cell walls |
| | Never have cilia or flagella | May occasionally have flagella | Cells sometimes have cilia or flagella |
| | Simple can be unicellular or made up of long threads of hyphae. Large such a mushrooms produced by compacted masses of hyphae | | Communication by nervous system |

***Viruses*** are not classified in the 3 domain classes as they are considered dead (they don't undergo MRS GREN), also they do not have any of the features that are used in the classification.

- Structure only visible by electron microscope
- Acellular- they do not have cellular structure like bacteria and fungi
- Infectious but have no metabolism when they are free
- When infected, they use the biochemical machinery of the host cells to copy their nucleic acids and make their proteins → destruction of host cell.

**Taxonomic system for viruses:**

- Is based on the diseases which they cause
- Type of nucleic acid they contain (DNA or RNA)
- Whether nucleic acid is double/single stranded

Note: in cellular organism's DNA is double stranded and RNA is single stranded but in viruses both can be either single or double.

## 3. CONSERVATION

### *3.1 Threats to Biodiversity*

Five major threats to biodiversity:

- Habitat loss and degradation of environment
- Climate change
- Excessive use of fertilizers and industrial and domestic forms of pollution
- Over exploitation and unsustainable use of resources
- Alien species

  - **Habitat loss:** process in which habitat is rendered functionally unable to support the species present. In this process, the organisms that previously used the site are displaced (**habitat fragmentation**) or destroyed, reducing biodiversity and leading to extinction in extreme cases.
  - **Deforestation:** leads to severe land degradation as a result of soil erosion.
  - **Climate change:** a simple climate change can effect plants and animals as they may not be able to adjust. This change is also caused by **greenhouse** gases that we emit to the air, from organic waste to factories. As it acts as a barrier that traps heat causing global warming which in return causes rise in sea levels.
  - Acidification/temp rise of the oceans can destroy the aquatic life such as coral reefs, algae and molluscs.
  - Coral reefs alone are one of the most diverse ecosystems. We rely on them for protection. They have been destroyed due to **overfishing**, mining and fertilizer run-off.
  - Pollution caused by industries and domestic such as sewage and toxic industrial waste is sometimes with no treatment leaked into the environment, effecting animals' metabolism or excretion. Substances such a PBCs enter our food chains and this effects our immune systems and reduces fertility.
  - Also some **non-biodegradable** such as plastic can be mistakenly eaten by turtles mistaking it for jelly fish.
  - Fertilizers can drain into rivers causing eutrophication which kills all species life in that ecosystem.
  - Air pollution causes acid rain and as mentioned earlier would affect aquatic life and vegetation.
  - **Over exploitation:** hunting, fishing and poaching.
  - **Alien species:** are invasive species that moved from one ecosystem to another. This has happened by trading animals, unwittingly carrying them on ships and finally used to control pests.
  - **Increase in Disease** alien species could also introduce diseases

- Push species to extinction
- Introduce diseases
- Compete for resources
- Impact biodiversity
- soil degradation, and erosion

### *3.2 Why does Biodiversity Matter?*

- **Moral and ethical:** some people believe we have no right to cause extinction of other species, as they value other species and believe we must share the planet.
- **Ecological:** loss of species can cause an unbalance which may have implications for the survival of other species.
- **Aesthetic:** many people like to enjoy the variety of organisms and habitats of earth. It can be important for studying and also income due to tourism.
- **Social and commercial:** animals or plants that are important to the economy of countries for food or raw material e.g. selective/genetic/inter breading of crops and animals to introduce more useful alleles to increase yielding and useful characteristics.
- **Other services:** plants have an important role in keeping oxygen and carbon levels constant. Also organic wastes can act like fertilizers for crops nutrition requirements.

## 3.3 Protecting Endangered Species

**Zoo:** has a variety of functions in addition to providing enjoyment and interest for visitors who can study animals they would not be able to see otherwise.

- *Advantages:*
  - Protected, properly fed and given veterinary attention.
  - Provide protection for endangered species and captive breed so that in the long term they could reintroduce them to their natural habitat.
  - Maintain genetic diversity by breading with different males.
  - Research to better understand breeding habits, habitat requirements and ways to increase genetic diversity
- *Disadvantages:*
  - Not all conservation attempts are a success
  - Animals can refuse to breed in captivity
  - Sometimes not possible to create suitable habitats
  - Difficult for animals to adapt to wildlife as they were used to being cared for.
  - Does not have the skills required to survive:
    - Avoid predators
    - Find food
    - Rear their own

**Frozen zoos & seed banks:** storage facility in which genetic materials taken from animals (e.g. DNA, sperm, eggs, embryos and live tissue) are gathered and stored at very low temperatures for optimal preservation over a long period.

**Botanic gardens:** are similar to zoos for endangered plants, seeds or cuttings are collected from species in the wild and stored, for later use to be reintroduced to their natural habitats.

- *Advantages:*
  - Protect endangered plant species
  - Research methods of reproduction and growth, so they can be grown in appropriate conditions
  - Research conservation methods so plants introduced to new habitats
  - Reintroduce species
  - Educate public in the roles of plants in our ecosystem and their economic value
  - Contains seed banks where plant seeds are stored so that if any plant becomes extinct there would be seeds, which they can be grown from. Each 5 years seeds carry out germination tests.
- *Disadvantages:*
  - Possibility of altering genetic diversity
  - Gene pool decreases
  - Some plants are difficult to be dried and frozen

**Conserved areas (national parks):** set areas where wildlife and environment have some form of protection controlled by government, and where human activity is limited.

- *Advantages:*
  - Restricts humans from fishing and hunting
  - Tourism gains money to the country
  - Teaches how conservation takes place
  - Animals are not moved from natural environment
  - Closer feel to wildlife than zoos
- *Disadvantages:*
  - Threats are still so great some species have to be moved
  - Animals are restricted in specific area (cannot migrate)

## 3.4 Methods of Assisted Reproduction

Assisted reproduction is a solution for inbreeding problems. Zoos do not have to transport large mammals for their captive breeding programs instead their sperm is taken and stored in a **sperm bank.**

- **Artificial insemination (AI):** is where a sperm is inserted into the vagina and inserted in the uterus using a catheter.
- **Embryo transfer:** is used when the animal is endangered and cannot be risked with pregnancy, so the embryo is flushed out and transferred to **surrogate** mothers.

## 3.5 Culling and Contraceptives

- **Culling:** is the process of killing/moving animals from a breeding stock based on specific criteria or due to it becoming a fast growing population
- **Birth control:**
  - Vasectomy (cutting male sperm duct)
  - Steroid hormones
  - Vaccine which targets layer of glycoprotein around the egg. When injected antibodies against glycoproteins stop sperm from fertilizing the egg - 90% success.

## 3.6 Non-Governmental Organizations

International conservational organization like:

- CITES
  - Agreement signed by 145 countries

- Controls trade in endangered and products from them e.g. fur, skin and ivory
- It has appendices which list endangered species according to set criteria

Species don't always benefit from this organization as when a product becomes illegal, then practice to obtain this product rises.

- WWF - World Wide Fund of Nature
  - Campaigning group for wildlife conservation
  - Funds conservation projects
  - Publicizes environmental issues
  - Campaigns to save ecosystems

## *3.7 Restoring degraded habitats*

- **Conservation** involves restoring areas that have been degraded by human activity or by natural catastrophes
- Small scale e.g. is when a farmer decides to plant trees on land that is no longer needed or has become degraded by overuse

e.g. after centuries of deforestation, soil erosion and severe land degradation in Haiti, efforts are made to restore forests. About 70% of the countries land is unsuitable for agriculture. There are numerous tree planting projects to rescue the agriculture.

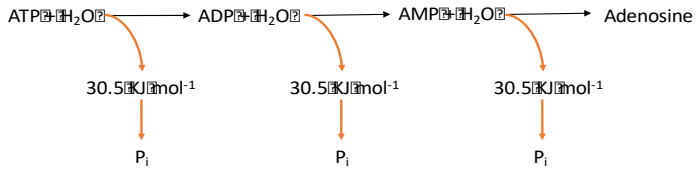
# 4. Energy and Respiration

## *4.1 Energy*

Energy is needed for work in living organisms e.g:

- Anabolic reactions: synthesizing complex substances from its monomers, such as protein synthesis
- Active transport of substances such as the sodium potassium pump
- Muscle contraction and cellular movement such as flagella or cilia
- Maintaining body temperature

## *4.2 ATP Adaptation for Universal Energy Currency*




Note: Energy does not come from breaking these bonds, but from changes in chemical potential energy.

- ATP is readily hydrolysed to release energy
- Immediate source of energy
- Small and water soluble; easily transported around cell
- Pi is a good leaving group, as ATP synthase can efficiently reattach the Pi to ADP.
- Links anabolic and catabolic reactions
- ATP is produced from a variety of reactions

**ATP synthesis**

| ATP can be synthesized by two routes | |
|---|---|
| **Substrate linked** | **Chemiosmosis** |
| • Glycolysis<br>• Krebs cycle | • Oxidative phosphorylation & ETC |
| Only oxidative phosphorylation requires oxygen as the it is needed to combines with electron/proton in the final acceptor. No ETC would mean no proton gradient produced ∴ Chemiosmosis does not occur. | |

## *4.3 Respiration*

Respiration is the process in which organic molecules act as a fuel

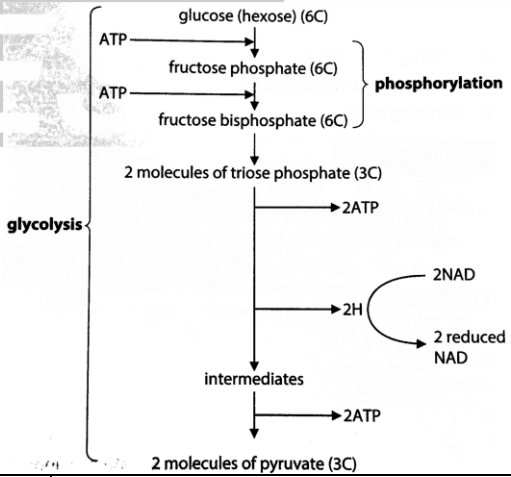
1. Glycolysis
2. Link reaction
3. Krebs cycle
4. Oxidative phosphorylation

} oxygen present

**Glycolysis**

Is the splitting, or lysis, of glucose to form 2 molecules of pyruvate (3C) which occurs in the Cytoplasm of the cell

- First stage is phosphorylating glucose using 2 ATP, this is done so that the reaction is easier

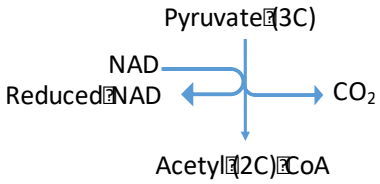



| Net Gain | 2 ATP and 2 Reduced NAD |
|---|---|

- The end product, pyruvate, still contains large amount of chemical potential energy therefore if oxygen available then Krebs cycle and oxidative phosphorylation is continued to make use of this energy.

**Link Reaction**

- Occurs in the Matrix of mitochondrion therefore must require pyruvate to actively be transported into matrix
- Decarboxylation occurs; which is the removal of $CO_2$
- Dehydrogenation also occurs: removal of $H_2$



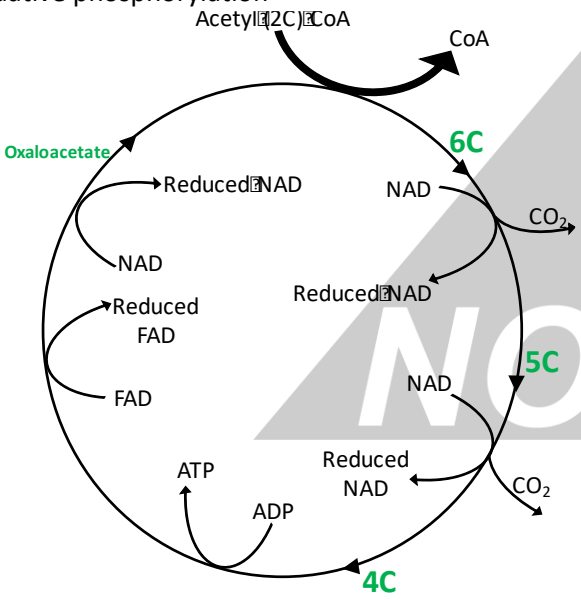

- Coenzyme A is a complex molecule composed of nucleoside (adenine plus ribose) with Vitamin, it acts as a carrier for acetyl groups to the Krebs cycle

| Net Gain | • $CO_2$<br>• Reduced NAD |
|---|---|
| Note: Remember there is 2 pyruvate molecules formed in glycolysis so net gain is 2 times | |

**Krebs Cycle**

Closed pathway of enzyme controlled reactions which also occurs in the matrix

- Although reaction is part of aerobic respiration the reactions make use of no oxygen it is only necessary for oxidative phosphorylation

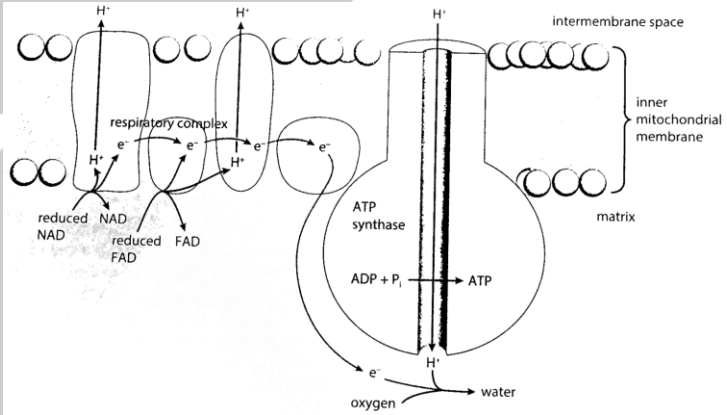



| Net Gain | • $2CO_2$<br>• 1 Reduced FAD<br>• 3 Reduced NAD<br>• 1 ATP |
|---|---|
| Note: Remember there is 2 acetyl CoA molecules so net gain is 2 times | |

**Oxidative Phosphorylation and the Electron transport chain (ETC)**

This stage chemiosmosis occurs which takes place in the inner mitochondrial membrane (Cristae)

- Reduced NAD and FAD are passed to the electron transport chain
- Reduced NADs and FADS release Hydrogen which then splits up into $H^+$ and $2e^-$
- Electrons flow down ETC release energy to pump $H^+$ ions from the matrix to the intermembrane space producing a proton gradient
- $H^+$ then move down conc. gradient through ATP synthase and form $H_2O$ by combining with oxygen and the $2e^-$
- ADP + $P_i$ → ATP , also occurs while the hydrogen passes through the ATP synthase and uses hydrogens electrical potential energy for chemiosmosis




Theoretically

- Reduced NAD produces 3 molecules of ATP
- Reduced FAD produces 2 molecules of ATP

However, some energy to transport ADP into the mitochondrion and ATP into the cytoplasm ∴ Realistically

- Reduced NAD produces 2.5 molecules of ATP
- Reduced FAD produces 1.5 molecules of ATP

| Net Gain | • Most ATP produced 28 molecules of ATP |
|---|---|

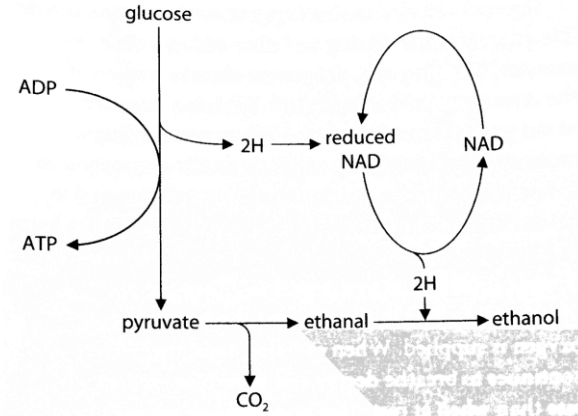
**Balance Sheet of ATP produced**

| | ATP used | ATP made | Net ATP |
|---|---|---|---|
| Glycolysis | -2 | 4 | +2 |
| Link reaction | 0 | 0 | 0 |
| Krebs Cycle | 0 | 2 | +2 |
| Oxidative phosphorylation | 0 | 28 | +28 |
| **Total** | -2 | 34 | **+32** |

## 4.4 Respiration without Oxygen

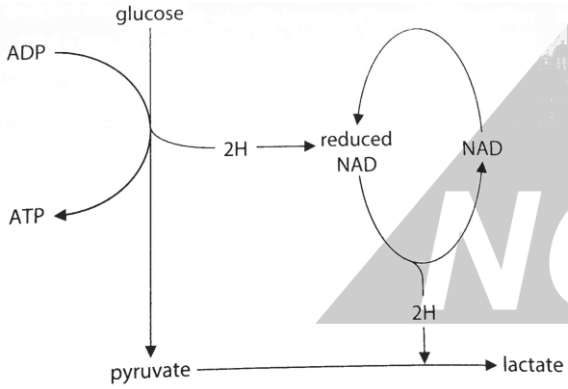
When no oxygen is present hydrogen can not be disposed in the ETC therefore chain stops and reduced NAD not oxidised hence soon Krebs cycle also stops. An alternative H acceptor (pyruvate) is reduced hence producing lactate

**In plants**




- Glycolysis takes place normally
- Then pyruvate is decarboxylated to ethanal and then reduced to ethanol by the enzyme alcohol dehydrogenase
- Reaction can not be reversed
- This conversion is called alcoholic fermentation

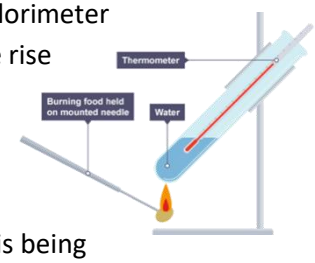
**In animals**




- Pyruvate is reduced to lactate by the enzyme lactate dehydrogenase
- Reaction could be reversed also by the same enzyme
- This happens by transporting the lactate produced to the liver by the blood plasma and is converted back to pyruvate
- Some (about 20%) is oxidized directly to form $CO_2$ and $H_2O$ in the liver when oxygen is available
- The remainder is converted by the liver to form glycogen

## 4.5 Respiratory substrate

- The more hydrogens per molecule a substance has the more energy or energy density
- This is because most of the energy liberated in respiration comes from oxidation of hydrogen to water
- To calculate the energy value of a substance burn a known mass with oxygen in a calorimeter
- The energy is determined by the rise in temp of the water





**Respiratory quotient ($RQ$)**

it is used to show what substrate is being used in respiration, it can also show whether or not anaerobic respiration is occurring

$$RQ = \frac{volume\ of\ CO_2\ given\ our\ per\ unit\ time}{volume\ of\ O_2\ taken\ in\ per\ unit\ time}$$

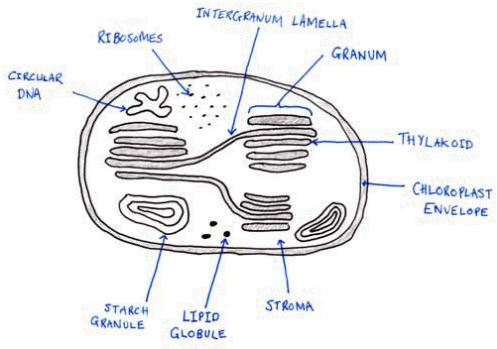
| Respiratory substrate | Respiratory quotient (RQ) |
|---|---|
| Carbohydrate | 1.0 |
| Lipid | 0.7 |
| Protein | 0.9 |

- When values are closer to infinity or higher than 1.0 this shows that aerobic respiration is occurring
- No RQ value for muscle cells as only lactate is produced with no $CO_2$ being produced

## 4.6 Adaptations of rice for wet fields

- Can respond to flooding by growing taller; always has parts such as leaves and flowers above water
- Contains loosely packed aerenchyma cells in the cortex of stems (formed by cell death) allowing diffusion for oxygen to be transported easily to areas deprived
- Contains ridges to trap oxygen underwater
- Can tolerate high levels of ethanol
- Produce more alcohol dehydrogenase which breaks down ethanol
- Ethanol stimulates gibberellin, which in turn stimulates cell division hence increasing length

# 5. PHOTOSYNTHESIS

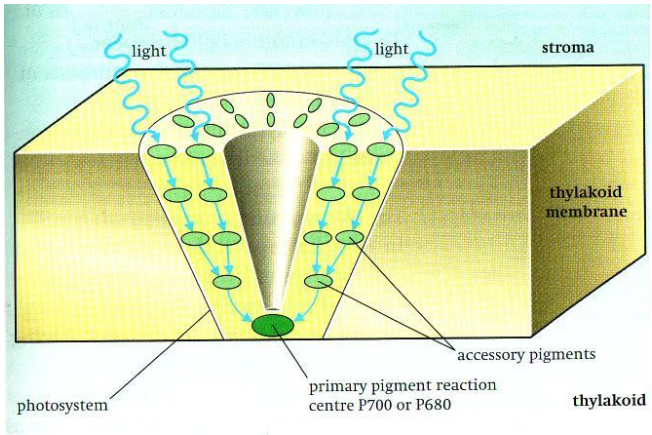



- Chloroplast biconvex about 3-10 µm
- Thylakoid membrane: where light-dependent occurs
  - Associated with chlorophyll, accessory pigments, ETC
- Grana: stacks of thylakoid membranes
  - Enclose hydrogen reservoir used in chemiosmosis
- Lamella: extensions forming a network between grana
- Stroma: Rubisco catalyses light independent reaction
- Starch granule → insoluble storage carbohydrate product of photosynthesis

**Adaptation of palisade tissue:**

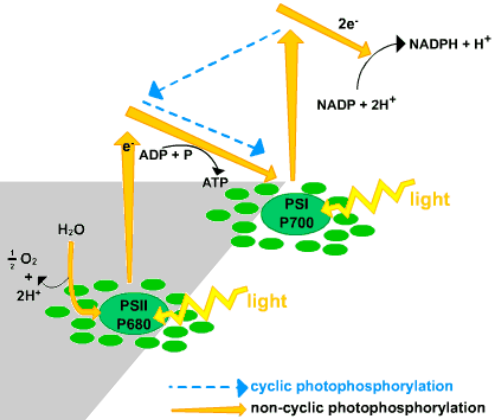
- Contain large numbers of chloroplasts
- Large vacuole helps in pushing chloroplast to edge of cell
- Chloroplasts at edge short diffusion path for carbon dioxide and absorb maximum light
- Chloroplasts can move towards light and away from intense light to avoid damage
- Elongated & arranged to intercept maximum light
- Closely packed to absorb maximum light
- Large surface area for diffusion of gases
- Moist cell surfaces for diffusion of gases
- Cell walls thin for maximum light penetration and diffusion of gases

## *5.1 Light Dependent Stage*




- Takes place in the thylakoid membranes
- Photosystems are required to trap wavelengths of light (photons) to energize the electron found in the primary pigment
- Accessory pigments are arranged in light harvesting clusters that pass on absorbed energy to the primary pigment (chlorophyll $\alpha$) at reaction center
- Photosystem I absorbs wavelengths of 700nm
- Photosystem II absorbs wavelengths of 680nm

**Non-Cyclic photophosphorylation**




1. Accessory pigments in PSII absorb photons of light, and the energy is passed onto primary pigment (chlorophyll$\alpha$) exciting primary pigments electrons (photoactivation) to a higher energy level causing them to escape and also causes the splitting (or photolysis) of water molecules
   $$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$$
   - Oxygen diffuses out of the chloroplast and into the air
   - The protons build up in the thylakoid lumen causing a gradient to be formed
   - The electrons in water replace the electrons that have left the primary pigment
2. The energized electrons are taken up by electron acceptor, and are passed down electron carrier chain. They are passed from PSII to carrier proteins, where the energy is used to pump protons from stroma to lumen; then to PSI, where more light energy is absorbed by the chlorophyll molecules and the electrons is reenergised.
3. The Electrons then recombine with a proton to form a hydrogen atom, which is taken up by the hydrogen carrier NADP forming Reduced NADP
4. The combination of the water splitting and the proton pumping caused protons to build up inside the thylakoid lumen, generating a proton gradient across the thylakoid membrane. ATP is therefore photophosphorylated using the ATP synthase enzyme in exactly the same way as respiration.

**Cyclic photophosphorylation**

- Only involves Photosystem I
- Electron photoactivated and instead of falling back into the photosystem and loosing energy as thermal energy, the excited electron is captured by electron acceptor
- It is then passed on via a chain of electron carriers, during which, enough energy is released to synthesize ATP by chemiosmosis
- Electron then returns back to Photosystem I

**Difference between cyclic and non cyclic**

Cyclic photophosphorylation:

- Only Photosystem I takes part
- Electron emitted returns to same photosystem

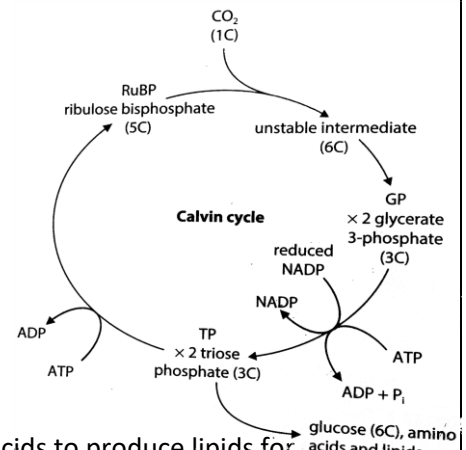
Non-cyclic photophosphorylation:

- Electron emitted from PSII absorbed by PSI
- Reduced NADP produced
- Photolysis occurs and produces oxygen

## 5.2 Light Independent Stage

- Occurs in the stroma of chloroplast and is called the Calvin Cycle
- ATP and Reduced NADP is taken from the light dependent stage

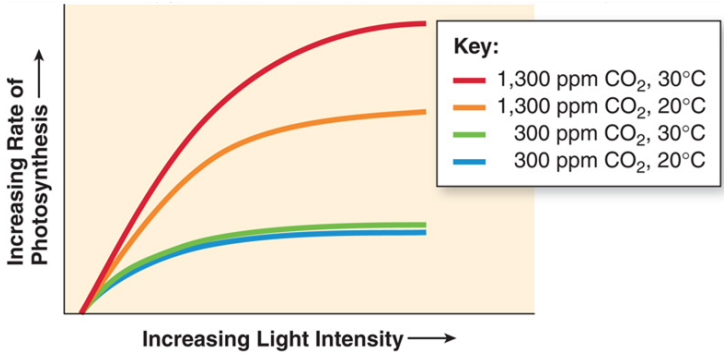
1. Carbon dioxide binds to the 5-carbon sugar ribulose bisphosphate (RuBP) to form an unstable intermediate, this is catalysed by the enzyme rubisco. The intermediate is then broken down to form 2 molecules of (3C) glycerate phosphate (GP).
2. GP is reduced and activated to form triose phosphate (TP). The ATP and NADPH from the light-dependent reactions provide the energy for this step. The ADP and NADP return to the thylakoid membrane for recycling
3. Most of the triose phosphate continues through a series of reactions to <u>regenerate</u> the RuBP <u>using ATP</u> and complete the cycle



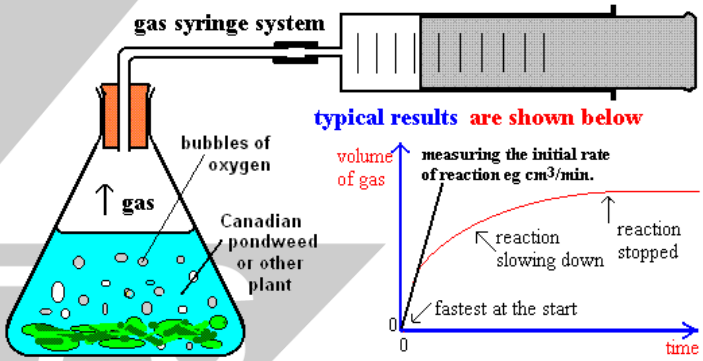

a. Some of the triose phosphate molecules combine to form glucose, starch for storage, cellulose for cell walls and sucrose for translocation around the plant.

b. Others converted to glycerol and fatty acids to produce lipids for cell membranes or acetyl coenzyme A (CoA).

## 5.3 Limiting Factors




- Three factors can limit the speed of photosynthesis: light intensity, carbon dioxide concentration and temperature. Without enough light, a plant cannot photosynthesise very quickly, even if there is plenty of water and carbon dioxide.
- At low light intensities, the limiting factor for rate of photosynthesis is the light intensity; as the intensities increase so does the rate. But at high light intensity, one or more other factors must be limiting, such as temperature or carbon dioxide supply.
- The effects of limiting factors can be investigated using aquatic plants such as *Elodea* or *Cabomba.*



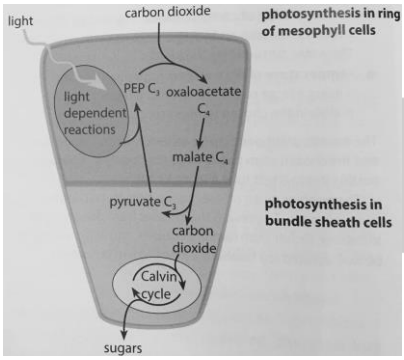

- The number of bubbles produced in unit time can be counted in different conditions
- A better method would be to calculate the volume of gas produced

## 5.4 Glasshouses

- A better understanding of the environmental factors on rate of photosynthesis, allows us to manage the growth of plants in protected fields increasing yield of crop.
- Sensors monitor light intensity, humidity and concentration of $CO_2$ and control optimum conditions
- Plants are grown in nutrient soil solution where its contents vary depending on the plants stage of growth
- Pests and fungal diseases are fewer, further improving yield

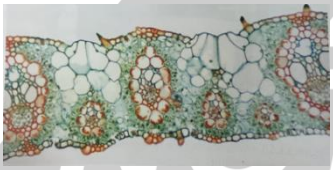
## 5.5 C4 Plants

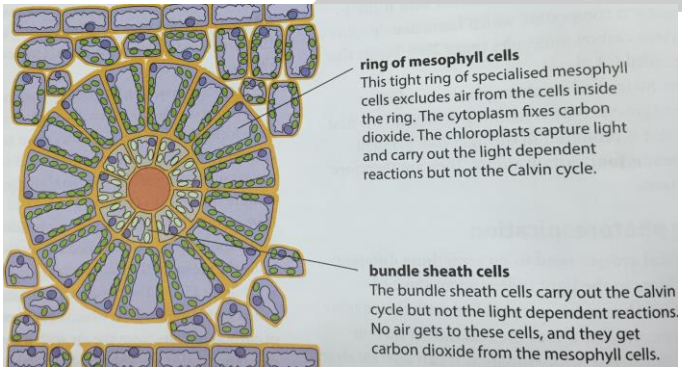
- C3 plants are known as C3 as it forms a 3 carbon molecule after splitting the six-carbon compound during the light independent stage of photosynthesis
- C4 plants such as maize and sorghum however, first compound that it produces in the light independent reaction is a four carbon compound
- Photorespiration: is the reaction when RuBP combines to the oxygen instead of the normal $CO_2$ so calvin cycle can not occur
- This usually happens in high temperatures (as stomata close to prevent water loss) and high light intensity.




- In C4 plants the Calvin cycle occurs in the bundle sheath

1. Carbon dioxide is absorbed by mesophyll cells that contain the enzyme PEP carboxylase which catalyses the combination of $CO_2$ with PEP
2. Oxaloacetate is formed and is converted into malate
3. It is then passed onto the bundle sheath cells and $CO_2$ is removed forming pyruvate
4. The $CO_2$ continues in its normal way and joins with RuBP by rubisco



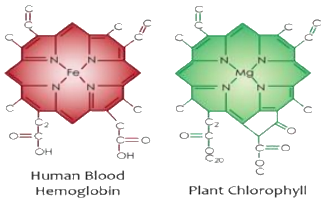



**Adaptation**

- Higher optimum temperature than C3 plants (45 °C)
- Mesophyll cells tightly packed so not allowing $O_2$ to reach bundle sheath cells
- Avoids photorespiration

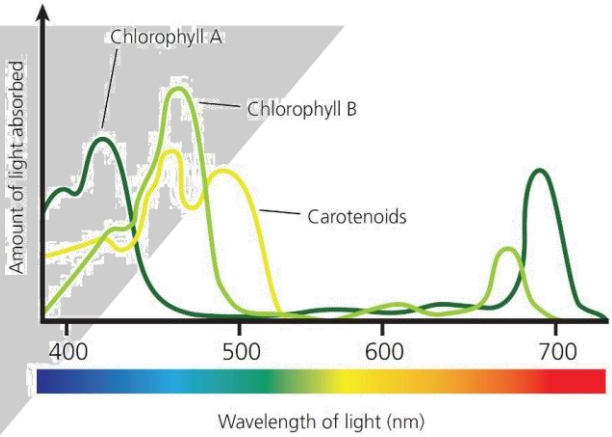
## 5.6 Pigments and the Absorption of Light

- There are two groups of pigments
  - Chlorophylls (Primary Pigments)
    - Chlorophyll is a small molecule with a structure similar to haem, but a magnesium atom instead of iron

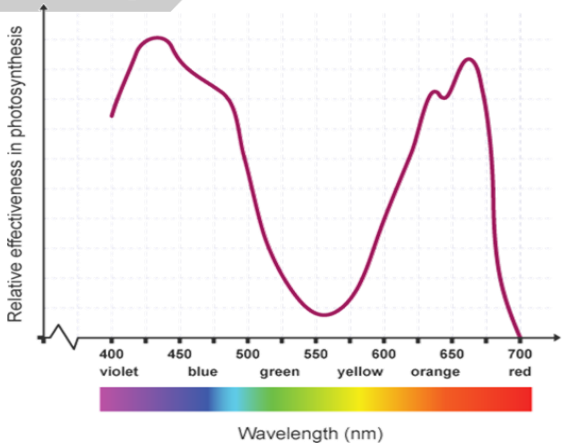



  - Carotenoids (Accessory Pigments)

| Pigment | Colour |
|---|---|
| Chlorophyll $\alpha$ | Green |
| Chlorophyll $\beta$ | Blue |
| $\beta$ carotene | Orange |
| Xanthophyll | Yellow |




- Absorption spectrum is the graph above and shows the absorbance at different wavelengths of light
- A low absorption means that those wavelengths are not absorbed, but instead are reflected or transmitted ∴ plants seem to be green as its is absorbed least
- An action spectrum however is a graph that shows rate of photosynthesis at different wavelengths of light

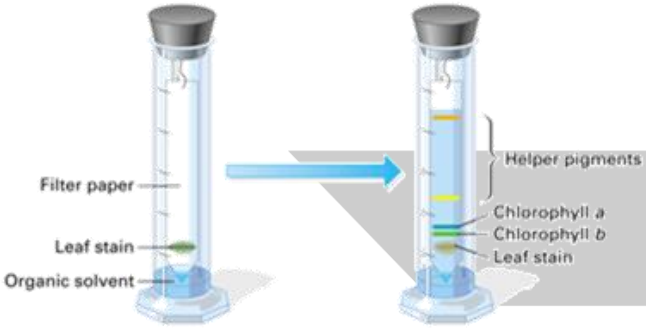



- Note that rate is higher at lower wavelengths this is not only due to greater absorption but also as lower wavelengths contains more energy

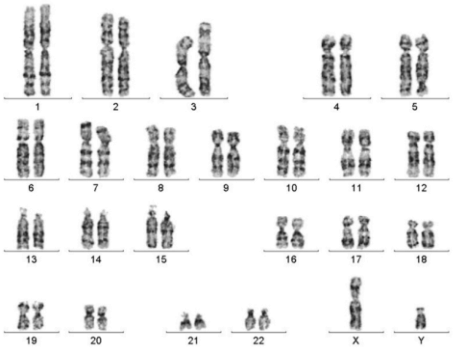
**Chromatography**

1. Grind leaf with solvent such as propanone
2. Leaf extract contains mixture of pigments
3. Draw a pencil line drawn and place extract on it
4. Place paper vertically in jar of different solvent
5. Solvent rises up paper with each pigment traveling at different speeds hence pigments separated
6. Distance moved by each pigment is unique
7. Use $R_f$ value to identify each pigment

$$R_f = \frac{distance\ travelled\ by\ pigment}{distance\ travelled\ by\ solvent}$$



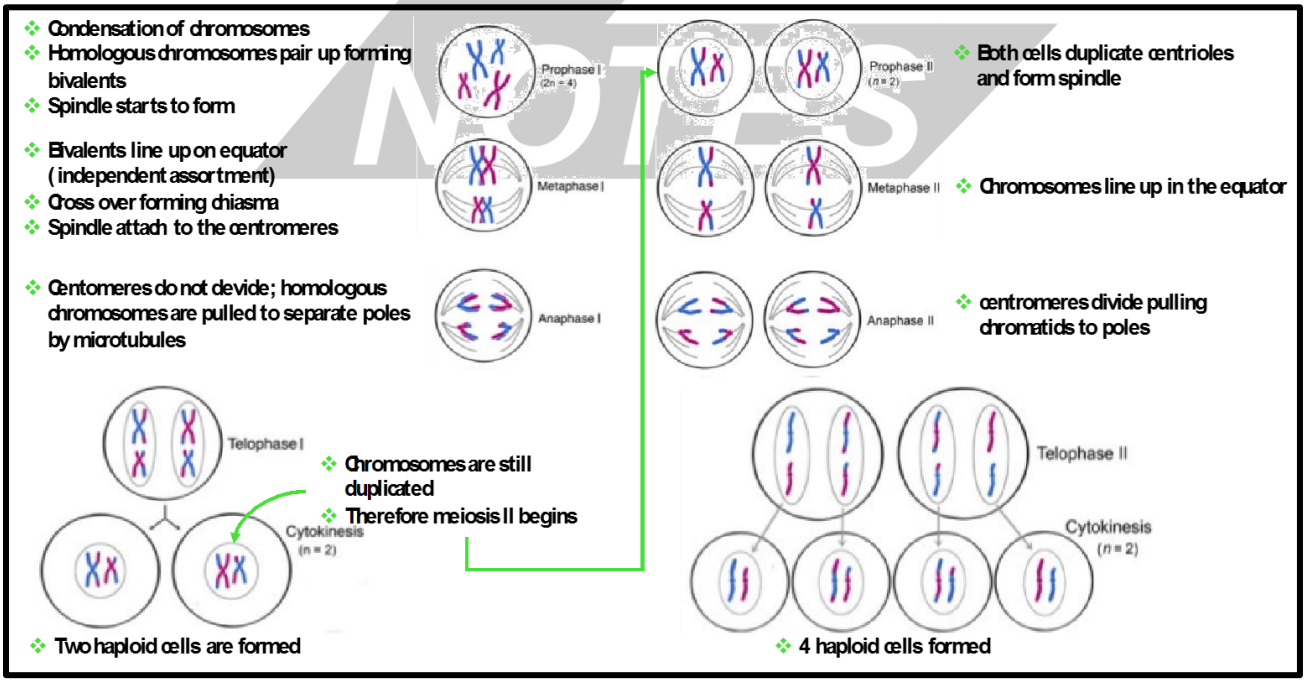

## 6. Inherited Change

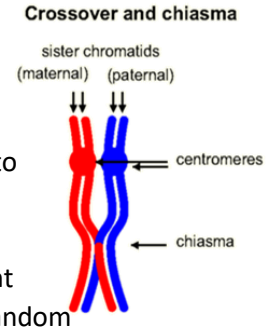



- A karyogram shows chromosomes that are rearranged into homologous pairs
- There are 22 similar pairs of chromosomes which is known as homologous pairs, from the pair one comes from the mother and the other comes from the father
- The 23rd pair however are non matching and are called sex chromosomes, whereas the 22 are called autosomes
- Chromosomes can be distinguished by staining it, each pair has distinctive banding patterns
- **Homologous chromosomes:** pair of chromosomes in diploid cell that have same structure as each other, with the same genes (may not be same allele) at the same loci
- **Gene:** a length of DNA that codes for a particular protein

## *6.1 Meiosis*

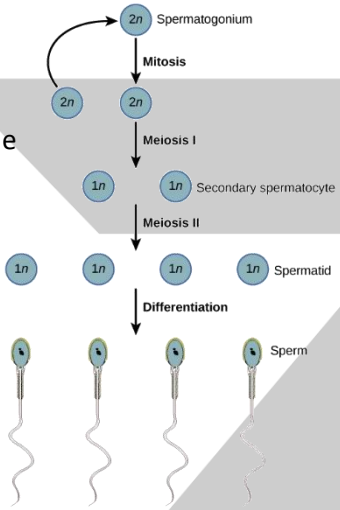
- Described as reduction division because chromosomes are halved from diploid (2n) cells to haploid (n)
- This is so chromosomes don't double every generation and so chromosome number is kept constant
- Also causes genetic variation for gametes which is the raw material for natural selection in species






- Variation caused:
  - During late prophase $I$ where crossing over takes place, two chromosomes (bivalents) attach to each other forming chiasma and switch genetic information
  - During metaphase $I$, independent assortment occurs which is the random lining up of homologous chromosomes across the equator and so maternal and paternal genes can mix

## 6.2 Gametogenesis in Humans




**In males:**

- Takes place in the tubules of the testes
- Germinal epithelial cells divide by mitosis to produce diploid **spermatogonia** which grow (increase in size) to from **primary spermatocytes**
- The cells then divide by meiosis $I$ to form 2 haploid **secondary spermatocytes** and continue with meiosis $II$ forming 4 **spermatids** which mature into **spermatozoa**

**In females:**

- Takes place in the ovaries
- Germinal epithelial cells divide by mitosis to produce diploid **oogonia**
- Meiosis is started but stops at Prophase I at this stage it is Primary oocyte (still diploid)
- All this occurs before a baby girl is born and at birth has around 400 000 primary oocytes
- At puberty meiosis continues to end of first meiotic division and becomes **secondary oocyte**
- However, division is uneven the other half (Polar body) doesn't have enough cytoplasm and so is of no more use
- Each month one secondary oocyte is released to get fertilised, it continues to divide to form an ovum
- If ovum is fertilised, then a diploid cell is formed called a zygote → embryo → fetus

**Difference in the processes of male and female gametogenesis**

| Male | Female |
|---|---|
| Produces sperm | Produces oocyte |
| Division of cytoplasm is equal | Division of cytoplasm is unequal |
| Four gametes produced | One gamete produced |
| No polar bodies | Polar bodies |
| There is a maturation stage | No equivalent maturation stage |
| Complete meiosis | Incomplete meiosis |

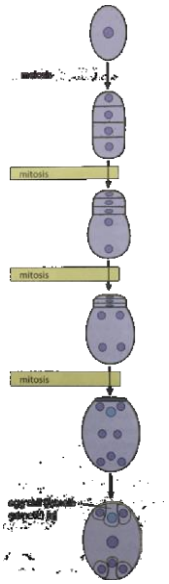
## 6.3 Gametogenesis in Plants

**In males**

- Takes place in the anther
- **Pollen mother cells** divide by meiosis forming 4 haploid cells.
- Each of these cells divide by mitosis but cytokinesis does not take place resulting in a cell with two haploid nuclei
- These cells mature into **pollen grains**, one of the nuclei is the **tube nucleus** and the other is **generative nucleus**

**In females**

- Takes place in the ovules
- Similar to the male**, Spore mother cell** divides by meiosis to produce four haploid cells
- All but one **degenerates**, this cell develops into an **embryo sac**
- Embryo sac divides by mitosis 3 times forming 8 haploid nuclei, of which one becomes the female gamete
- Note: In plants, unlike animals, gametes are not formed directly from meiosis, instead meiosis is used in producing the pollen grains and embryo sac which then forms gametes by mitosis




## 6.4 Genetics

- **Alleles** are different varieties of the same gene
- A **dominant** allele is one whose effect on the phenotype of a heterozygous is identical to one of a homozygote
- A **recessive** allele is one who does not express itself when a dominant gene is present
- **Codominant** alleles have both the phenotypes of each allele in a heterozygous organism

- A **test cross** is a genetic cross in which a dominant allele is crossed with a homozygous recessive; the offspring phenotypes can help judge whether its homo/hetro
- **F1 generation** is crossing homozygous dominant with homozygous recessive
- **F2 generation** is crossing two heterozygous (F1) organisms

## 6.3 Monohybrid Crosses

- A monohybrid cross is a mating between two individuals with different alleles at one genetic locus of interest

| mono-hybrid | | |
|---|---|---|
| Aa x Aa | | |
| | A | a |
| A | AA | Aa |
| a | aA | aa |
| Phenotype - 3:1 (normal : albino) | | |
| Genotype - 1:2:1 (normal : het for albino : albino) | | |

## 6.4 Multiple Alleles

- Three or more alternative forms of a gene, only two of which can exist in any normal, diploid individual.

| Phenotype (Blood Type) | Genotype | Antigen on Red Blood Cell | Safe Transfusions | |
|---|---|---|---|---|
| | | | To | From |
| A | $I^AI^A$ or $I^Ai$ | A | A, AB | A, O |
| B | $I^BI^B$ or $I^Bi$ | B | B, AB | B, O |
| AB | $I^AI^B$ | A and B | AB | A, B, AB, O |
| O | $ii$ | none | A, B, AB, O | O |

## 6.5 Sex Inheritance

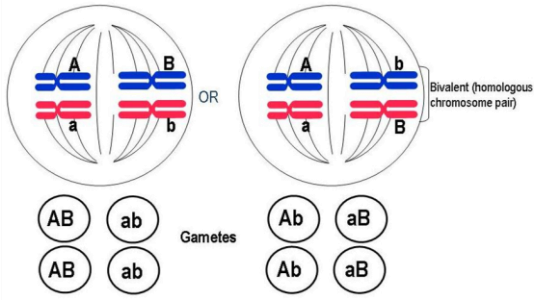
- Sex is determined by the autosomal chromosomes
- There are two types of chromosomes X and Y
- Y chromosome is much shorter than X and may not have some genes that X contains
- A person with XX chromosomes is female and XY is male
- Your gender is determined by the father's sperm as mother always gives the X chromosome (1:1 chance)

## 6.6 Sex Linkage

- X chromosomes contain a gene that codes for blood clotting which is called the factor VIII, the recessive allele causes the disease haemophilia (blood fails to clot)
- This is considered to be a sex linked gene as it is found on the X chromosome but not found on the Y
- When inherited females will have 2 X chromosomes and males would have 1
- Therefore, females have a chance to cover the recessive allele by its other X chromosome so will only be a carrier
- But males have no other X so if the mother has passed on the recessive allele the boy will have haemophilia
- Genotypes of sex linked genes are always represented by symbols that are on the X chromosome e.g. $X^HX^h$ (carrier)

## 6.7 Dihybrid Crosses

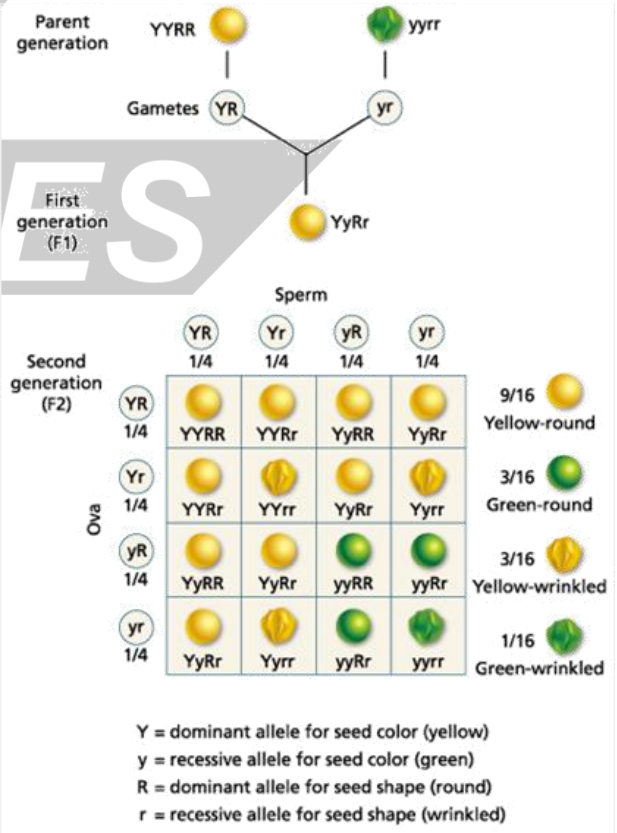
- Deals with the inheritance of two separate genes on different chromosomes at once (e.g. eye colour and skin)
- When cells undergo meiosis to produce gametes, the homologous pairs line up independently of each other




- Hence we can predict gamete produced would be of 4 types AB,Ab,aB and ab occurring in equal numbers
- A heterozygous dihybrid cross with a homozygous species would give a 1:1:1:1 simple ratio
- A dihybrid cross of two heterozygous species is a little more complicated and longer

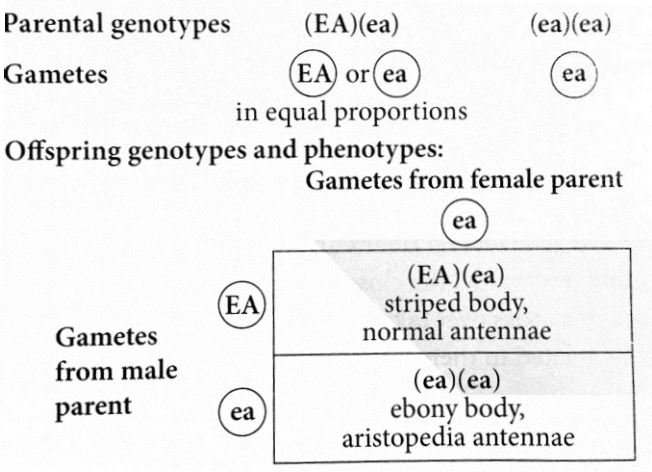
## 6.8 Interactions Between Loci

- Interactions between alleles at the same locus is what we have learnt till now
- But now we need to see what happens when different loci interact to effect one phenotypic character



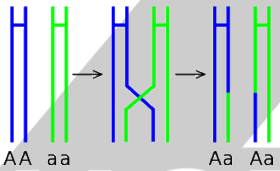
## 6.9 Autosomal Linkage

- **Linkage:** is the presence of two genes on the same chromosome, so that they are inherited together and do not assort independently
- Linked chromosomes written in brackets to indicate that they are on the same gene e.g. (EA)(EA) instead of EEAA
- Mating heterozygote and homozygous recessive gave us 1:1:1:1 in dihybrid crosses but in linked we get 1:1




- The dihybrid acts as though it is monohybrid cross
- Total linkage is very rare, almost always links are broken due to crossing over during meiosis

## 6.10 Crossing Over




- Occurs during prophase I where chiasmata formed between bivalents
- Chiasmata connects with a non sister chromatid so maternal and paternal genes are exchanged
- When these exchanged genes form offspring they are said to be **recombinant** offspring
- **Cross over value** is calculated by adding the percentage of offspring that belong to recombinant classes
- This value can be used to measure the distance apart of the two gene loci

Chance of cross over ∝ distance apart

## 6.11 Chi-squared ($x^2$) Test

- Ratios such as the 9:3:3:1 are only probabilities of inheriting the phenotypes
- Though what we observe may not always be exactly the same as the expected probabilities but somewhat close to it, so to test whether the difference is sufficiently close to say that the difference has arisen is due to chance we must use the Chi-squared test
- **Null hypothesis:** Null hypothesis always goes against the hypothesis being true
- E.G. in most cases it is that, observed results are not significantly different from expected results

$$x^2 = \frac{\Sigma(O-E)^2}{E}$$

Blue colour indicates that this formula will be provided in the exam

1. First work out expected (E) results by using ratio given

$$\frac{phenotype}{total\ phenotypes} \times number\ of\ offspring$$

2. Then find the difference between observed (O) and expected and square it

Giving $(O-E)^2$

we square to get rid of the negative sign as it is irrelevant

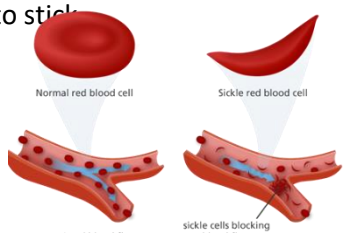
3. We then divide each squared number by E and add them up to give us $x^2$
4. Now you look up the value in a probability table to see if null hypothesis will be accepted or rejected
5. You must find the degrees of freedom which is = number of different categories – 1
   - If probability lower than the probability in the table, we accept the null hypothesis, meaning the results are just due to chance and so no significant difference
   - And if greater or equal, then we reject null hypothesis hence difference must be significant

## 6.12 Mutation

- **Mutation:** unpredictable change of the nucleotide sequence in DNA that may be for the better or worse
- Two types of mutation:
  - **Gene mutation** which is change in the structure of DNA molecule producing different allele of a gene
  - **Chromosome mutation** changes in structure or number of whole chromosomes in cell
- Gene mutation can occur in 3 different ways
  - Base substitution where simply one base takes another bases place
  - Base addition where on/more extra bases are added
  - Base deletion where bases are lost from sequence
- Base addition and deletion always have large effects as it alters every set of three bases (**frame shift**) but in base substation only effects the one substituted and this may not even have an effect at all (**silent mutation**), as there is more than one base triplet that can form the same amino acid
- However, all mutations at times when the cause a stop triplet to form can have large effects as protein stopped

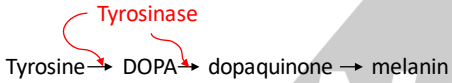
## 6.13 Sickle Cell Anaemia

- Is an example of base substitution
  - Where the $\beta$-globin polypeptide mutates
  - The base sequence CTT is replaced by new triplet CAT
  - Which changes the 6th amino acid from Glu to Val
- This small difference does not effect the haemoglobin molecule when combined with oxygen
- But when not combined the $\beta$-globin molecule becomes much less soluble and starts to stick to each other forming long fibbers inside red blood cells, and so pull out of shape and become sickle shaped
- They also get stuck in small capillaries, restricting blood flow




## 6.14 Albinism

- Is where a dysfunctional enzyme can cause such difference in phenotype
- Albinism is when the pigment melanin is deficient or completely missing from our eyes, skin and hair
- The condition also can be accompanied by poor vision causing jerky movements of the eye to avoid light
- It is an autosomal recessive mutation which must be homozygous for the recessive allele to show albinism
- The enzyme **tyrosinase** is responsible for melanin production as it is needed in the first two steps



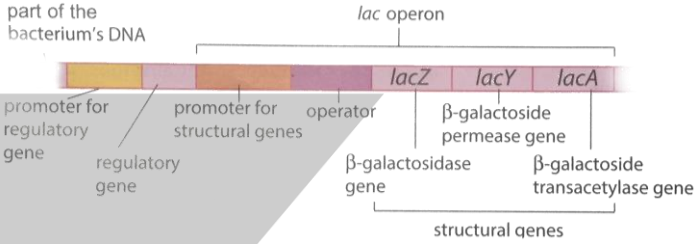

- Tyrosinase is a transmembrane protein that has two copper atoms in its active site which bind to oxygen

## 6.15 Huntington's Disease

- This disease unlike the previous two is a mutation inherited as a dominant allele
- HD has a variable onset but occurs most commonly in the middle age (30-45)
- It is a neurological disorder that causes involuntary movements and progressive mental deterioration
- Brain cells lost & ventricles in the brain become larger
- Mutation occurs on chromosome 4 on a gene that codes for huntingtin
  - unaffected have small number of triplet CAG repeats
  - large number of CAG repeating which causes stutter
- There is an inverse correlation between number of times triplet repeats and onset age of condition

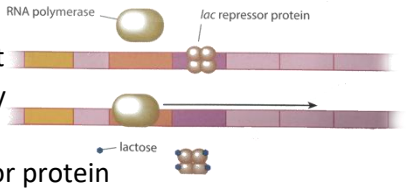
## 6.16 Gene Control in Prokaryotes

- **Structural genes** are genes that code for proteins or enzymes required by a cell
- **Regulatory genes** are genes that code for proteins that regulate the expression of other genes
- **Repressible enzymes** are produced continuously unless production is repressed by binding a repressor protein to the operator
- **Inducible enzymes** are only produced when its substrate is present. Transcription of the gene occurs as a result of the inducer (the enzyme's substrate) interacting with the protein produced by the regulatory gene



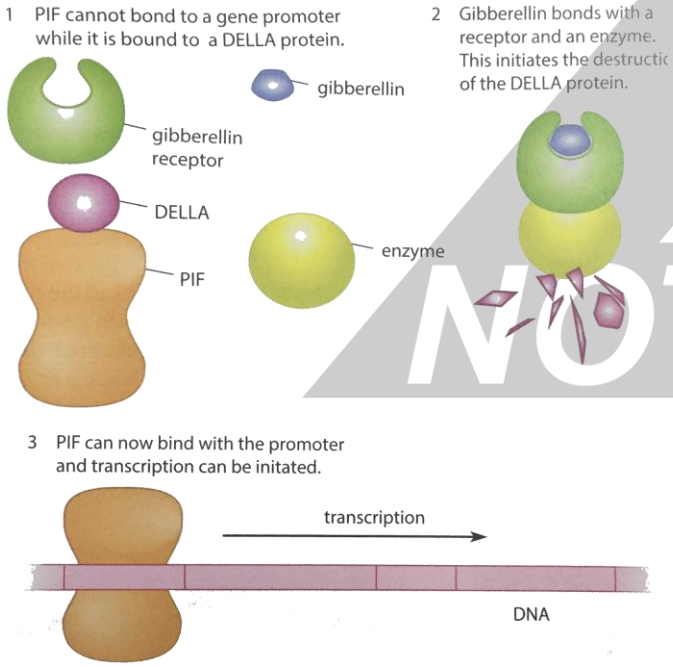

**The Lac Operon**

- An Operon is a length of DNA containing adjacent genes including structural genes and an operator gene and a regulatory gene
- The enzyme $\beta$-galactosidase (inducible enzyme) hydrolyses lactose to glucose and galactose
- The lac operon consists of promoter, operator and 3 structural genes which are:
  - $lacZ$ which codes for $\beta$-galactosidase. $LacY$ which allows lactose to enter cell and $lacA$
- When no lactose present
  - Regulatory gene codes for repressor
  - Repressor bind to operator
  - RNA polymerase cannot bind to DNA
  - ∴ No transcription occurs
- The repressor protein is allosteric. Meaning it has two binding sites and for this case lactose (substrate) binds into the allosteric site.
- When lactose is present
  - Lactose is taken up by bacterium
  - And binds to repressor protein distorting its shape and so preventing it from binding to operator
  - Transcription is no longer inhibited and RNA produced
- This mechanism helps avoid waste of energy and materials by only creating enzymes when required



## 6.17 Gene Control in Eukaryotes

- Transcription of a gene is controlled by **transcription factors**; which are proteins that bind to a specific DNA sequence and control the flow of information from DNA to RNA by controlling mRNA formation
- Functions of transcription factors:
  - Form part of protein complex that binds with promoter region
  - Activate appropriate genes in sequence allowing correct pattern for body development
  - Responsible for the determination of sex in mammals
  - Allows responses to environmental stimuli, such as switching on correct genes in high temp
  - Regulate cell cycle, growth and apoptosis (cell death)
- The plant hormone, gibberellin controls seed germination by stimulating the increase of transcription of mRNA coding for amylase
- Gibberellin does this by breaking down DELLA proteins which inhibit the binding of transcription factor, PIF to a promoter
- Transcription can then take place resulting in increase of amylase production




# 7. Selection and Evolution

Genetic variation is caused by:

- Independent assortment of chromosomes
- Crossing over between chromatids
- Random mating between organisms
- Random fertilisation
- Mutation

## 7.1 Continuous and Discontinuous Variation

**Continuous variation:**

- A quantitative difference that has a wide unbroken range of phenotypes
- Intermediate phenotypes are usually what is observed, plotting a frequency graph usually gives a bell shaped distribution curve
- E.g. Height and weight these do not have distinguishable classes but are in a range
- Many additive genes control the characteristic but is also majorly effect by the environment

**Discontinuous variation:**

- A qualitative difference that has clear distinguishable categories with no intermediates
- It is usually a one to one relation between genotype and phenotype
- E.g. Blood groups, there is only 4 possible ABO groups
- One or few genes control the characteristic, so alleles on single gene locus's have large effects unlike continuous

**Environmental effects on phenotype:**

- Two boys with the exact same genetic make up such as twins have the genes to grow a certain height, but usually one is taller this is due to the nutrition they each take which is an environmental factor

## 7.2 The t-test

- The t-test is used to assess whether the means of two sets of data are significantly different from one another
- Similar to the chi-squared test you always start with a null hypothesis stating that there is no significant difference between the two samples

$$t = \frac{|\overline{X}_1 + \overline{X}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

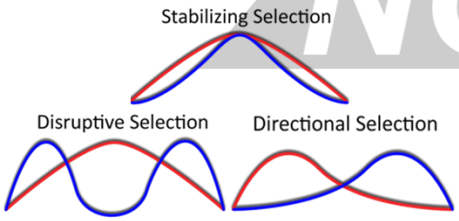
  - $\overline{X}_{1/2}$ is the mean of samples 1 and 2
  - $s^2_{1/2}$ is the standard deviation of samples 1 and 2
  - $n_{1\ /2}$ is the no. of individual measurements in 1 and 2
- We calculate the degrees of freedom by
  - =adding up all the samples — 2
- From the probability table we take 0.05 as being our critical value (also known as 5% confidence level)
  - If probability lower than critical value, null hypothesis accepted, so are just due to chance
  - If greater or equal, reject null hypothesis, not due to chance and difference must be significant

## 7.3 Natural Selection

- All organisms have the reproductive potential to increase their population rapidly, in fact they would increase exponentially if there is no limiting factor
- Environmental factors however keep the population low
  - **Biotic** – caused by living organisms e.g. predation, competition for food, infection, etc.
  - **Abiotic** – caused by non living organisms e.g. water supply, nutrient levels in soil, etc.
- These factors reduce the rate of growth for populations as many of the population fail to survive (die) hence don't reproduce
- There is a variation amongst the population and so those who are best adapted survive and reproduce passing on advantageous alleles to next generations
- This leads to changes in allele frequency and gene pool
- This genetic variation leads to change in phenotype and overtime produces evolutionary change; forming new species

## 7.4 Types of Selection Pressures

- Selection pressures increase the chance of some alleles being passed on to the next generation
- If the selection pressure keeps the variety of the population the same this is called **stabilising selection**
- If a new environmental factor or a new allele to appears this can cause different allele frequencies to be produced – **directional selection**
- **Disruptive selection** occurs when conditions favour both extremes of a population (this selection maintains different phenotypes)




## 7.5 Genetic Drift

- Genetic drift is a change in allele frequency that occurs by chance, because only some of the organisms reproduce
- It is most noticeable by **founders' effect** where a small population is isolated and so have different selection pressures, therefore allele frequencies change hence causing genetic drift and evolution of this population

## 7.6 Hardy-Weinberg's Principle

$$p + q = 1$$
$$p^2 + 2pq + q^2 = 1$$

- $p$ represents dominant allele frequency
- $q$ represents recessive allele frequency

- Hardy-Weinberg's principle does not apply when there is
  - Significant selective pressure against a genotype
  - Migration of population into or out
  - Non-random mating

## 7.8 Artificial Selection

| Artificial selection | Natural selection |
|---|---|
| Selection pressure applied is by humans | Environmental selection pressure |
| Genetic diversity is lowered | Genetic diversity remains high |
| Inbreeding is common | Outbreeding is common |
| inbreeding depression | less inbreeding depression |
| Increased homozygosity | Decreased homozygosity |
| No isolation mechanisms operating | Isolation mechanisms do operate |
| Usually faster | Usually slower |
| Selected feature is for human benefit | Selected feature is for organism's benefit |
| Not for survival/evolution | Promotes survival/evolution |

***Example of Selective breeding in***

**Improving milk yield:**

- Individuals showing desired features are chosen to breed
- Some of the alleles conferring these features are passed on to the offspring
- Again, most desired features are chosen for breeding
- This process is continued for many generations causing the frequency of the desired alleles to increase

**Improving crop:**

There are 3 types in this case:

1. **Introduction of disease resistance**, as there is a great loss of yield resulting from infections
2. **Incorporation of mutant alleles**, mutant alleles such as Rht gene (reducing height) are used as they cause the growth of shorter stems so more energy can be used in making seeds instead. This is caused by the gene coding for DELLA proteins that reduce effect of gibberellin
3. **Inbreeding and hybridization:**

- Inbreeding plants causes each generations gene pool to become progressively smaller and weaker this is known as inbreeding depression

- Out breeding produces heterozygous plants that are healthier and grow taller
- The aim is to get heterozygous and uniformity in genes
- Therefore, hybrid plants are used, these are taken from companies which inbreed to produce homozygous plants then cross them producing F1 generation with different homozygous varieties

## 7.9 Theory of Evolution

Charles Darwin forwarded the original theory that natural selection might be a mechanism by which evolution is formed by his observation and deductions:

**Observation**

- Organisms produce more offspring than what is needed to replace the parents (reproductive potential)
- Natural populations tend to remain stable in size

**Deduction**

- There is a competition for survival

**Observation**

- Variation amongst individuals of a given species

**Deduction**

- The best adapted variants will be selected by natural conditions, these are the variants that have a selective advantage and so 'survival of the fittest' occurs

This theory was put forward in the past, where they knew nothing about genes and alleles so now we can improve/add on to it by saying that, natural selection picks particular alleles or groups of alleles

## 7.10 Molecular Comparisons

Molecular comparisons allows us to see how similar and related species are to each other

**Comparing amino acid sequence of proteins:**

- When amino acid sequence is compared the number of differences gives a measure of how closely related the species are
- Differences in primary structure can cause dramatic change in structure and function however small changes can leave the overall structure and function same

**Example:**

Cytochrome C for example was compared between human, mice and rats

  - All three consisted of 104 amino acids
  - The sequence of mice and rat cytochrome is identical
  - 9 amino acids in human are different from rat/mice

- This comparison suggests that mice and rats shared a recent common ancestor, but not with humans

**Comparing amino acid sequence of mitochondrial DNA:**

- Difference in mtDNA can be used to study the origin and spread of species
- mtDNA is inherited through the mother only
- mtDNA is a circular and not protected by histone protein chain of DNA, that cannot undergo crossing over hence the only possible way of change is through mutation
- mtDNA mutates at around one mutation in 25000 years
- This has provided us with evidence that the origin of H.*sapiens* was from Africa around 200 000 years ago

## 7.11 Speciation

- Speciation is the evolutionary process by which new biological species arise
- The main feature biologists use to decide whether two organisms belong to different species is their inability to interbreed successfully (reproductive isolation)
- Reproductive isolation can take different forms:

**Prezygotic**

- Individuals don't recognise each other as mates or don't respond to mating behaviour
- Physically being unable to mate
- In ability to fuse male and female gametes
- Incompatibility of pollen and stigma in plants

**Postzygotic**

- Failure of cell division in the zygote
- Non-viable offspring (dies soon)
- Viable but sterile offspring

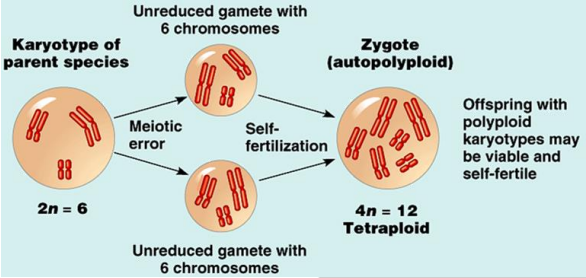
**Allopatric speciation:** when speciation occurs where two populations are separated from each other geographically

- Geographic isolation requires a barrier of some kind to arise between two populations of the same species
- Mixing of the two is prevented, and each have different selection pressures acting on the populations
- This results in different alleles being selected for hence overtime morphological, physiological and behavioural features becomes so different that the two populations even if barrier is removed can no longer interbreed

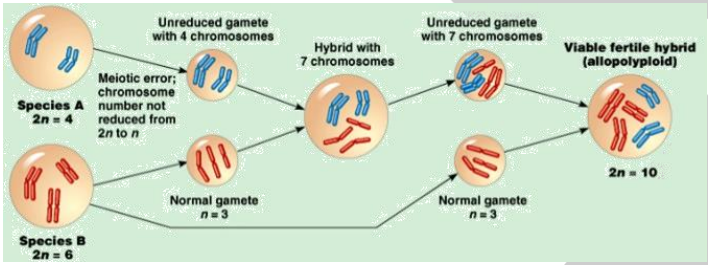
**Sympatric speciation:** is when a new species is evolved from a species that inhabits the same geographic region

- The most common way in sympatric speciation that can occur is by **polyploidy**
- A polyploidy is an organism with more than two complete sets of chromosomes in its cell
- This can happen if meiosis goes wrong when gametes are being formed so that gametes a have two sets

- If both the gametes have two sets they fuse and form a zygote with four complete sets which called a **tetraploid**
- If a diploid gamete joins with a normal gamete they form a **triploid** zygote
- Polyploids are often sterile as they can not divide during meiosis I due to it muddling up while pairing
- However, can grow perfectly well & reproduce asexually
- Autopolyploid: are polyploids with multiple chromosome sets derived from a **single** species




- Allopolyploid: is an individual or strain whose chromosomes are composed of **more** than two genomes




## *7.12 Extinction*

- Living organisms are dependent on the environment and other species for their survival. When the environment changes, organisms that cannot adapt become extinct
- There are many factors that can cause extinction: competition for food and resources, climate change, habitat loss, hunting, diseases

# 8. HOMEOSTASIS

Homeostasis is maintaining a relatively constant environment for the cells within the body, despite changes in external environment

- Homeostasis in general is controlled by controlling the composition of blood, and hence control the tissue fluid
- Tissue fluid influences cell activity in many ways such as:
  - **Temperature**- Low temp, slow metabolic reactions. High temp however denatures enzymes and proteins
  - **Water potential**- low water potential would cause water to move out of cells which slows/stops cell functions. High water potential however causes cells to swell and may burst
  - **Conc. of glucose-** Too less, no energy for cell to respire too high would effect osmotic balance and disturb cells

## *8.1 Homeostatic Control*

- Involves **receptor** (sensor) that detect stimuli that is being regulated
- Stimuli are any changes in a factor, such as temperature
- Receptor sends information to the central control in the brain or the spinal cord
- The input is processed and reacts by sending instructions to the effector, this action is a corrective action
- An **effector** such as muscles and glands cause the factor to return to its ideal value, **set point**
- This is done through two coordination systems:
  - Nervous system, electrical impulse along neurons
  - Endocrine system, in the form of chemical messengers (Hormones) that travel in the blood

**Negative feedback**

- Negative feedback is usually to keep factors within narrow limits, making it closest to set point as possible
- When a factor is increased it results in something that makes the factor decrease, and vice versa

**Positive feedback**

- Is not used in keeping conditions constant as it increases effect when stimulus is increased
- This is useful in other areas such as transmission of nerve impulses where the factor must be increased

## *8.2 Control of Body Temperature*

- This process is called thermoregulation and involves both the nervous and endocrine systems
- The hypothalamus is the central control for body temperature, it has thermorceptor cells that monitor the temperature of the blood. The skin also contains receptors that sense the change in temperature of the surroundings giving the hypothalamus an early warning

**Decrease in temperature**

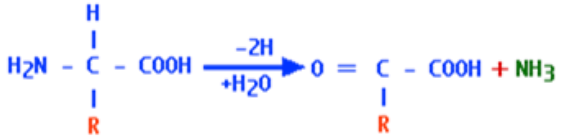
- Vasoconstriction- blood vessel walls contract causing restriction in blood flow to extremities where heat is easily lost
- Shivering- involuntary movement of skeletal muscle, generating heat for blood to absorb
- Raising body hairs- causing increase in depth of fur, hence increase the insulation as heat can be trapped
- Secretion of adrenaline & Thyroid stimulating hormone (TSH)- causes increase in metabolic rate, specially liver

**Increase in temperature**

- Vasodilation- vessel muscle relaxes, causing it to get closer to surface of the skin∴ losing heat to surroundings
- Lowering body hairs- reducing depth of fur, hence less insulation and more easy to lose heat
- Increasing sweat production- sweat produced causing more energetic molecules to escape and carry heat away

## 8.3 Excretion

**Deamination** is the removal of an amine group from a molecule. This is done in the liver when there is an excess of protein, rather than wasting a useful energy source




- The $-NH_2$ along with a hydrogen atom are removed leaving behind a keto acid
- The keto acid may enter the krebs cycle and be respired, or converted to glucose/glycogen/fat storage

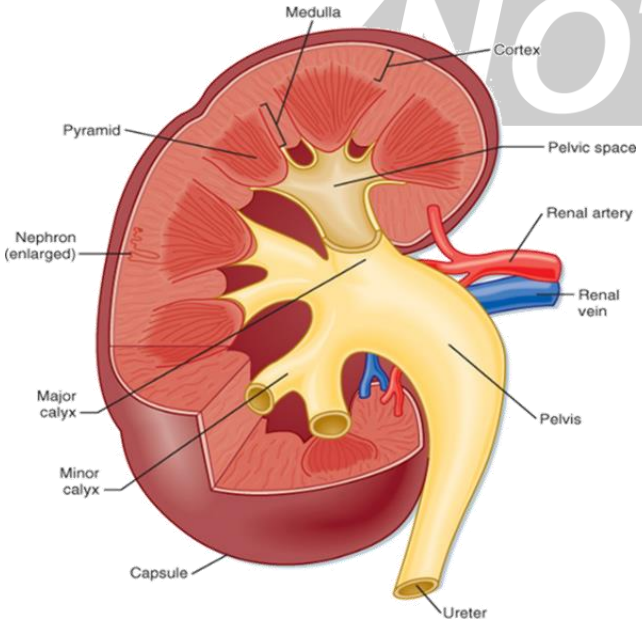
**Urea formation**

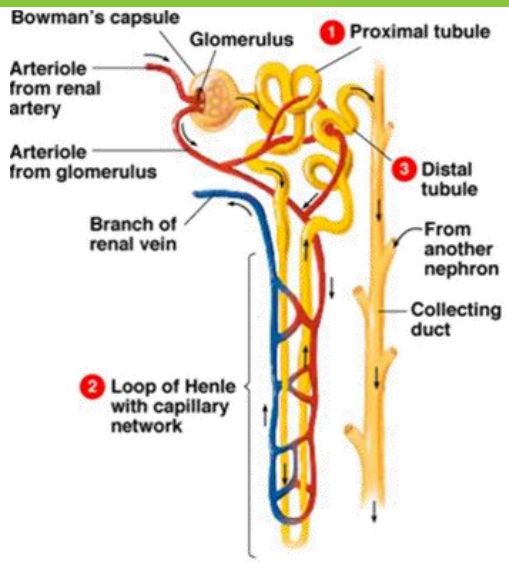
- Since ammonia is very soluble and highly toxic compound it is converted immediately to urea

$$2NH_3 + CO_2 \rightarrow CO(NH_2)_2 + H_2O$$

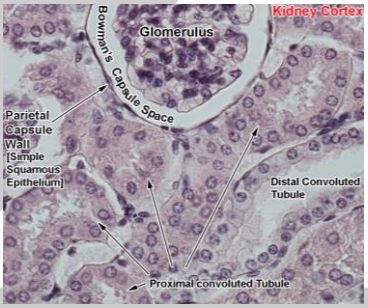
- Urea is the main nitrogenous excretory product, however we also produce creatinine and uric acid
- Creatine is made in the liver from amino acids that is used as an energy store in muscles
- Uric acid is made from the breakdown of purines

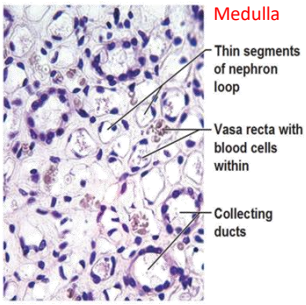
## 8.4 Structure of the Kidney




- Structures found above in the cortex are
  - Bowman's capsule
  - Proximal convoluted tubule (PVC)
  - Distal convoluted tubule DCT
- Lower down in the medulla are
  - Loop of henle
  - Collecting duct

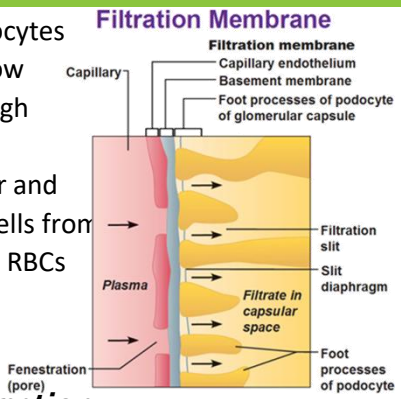



## 8.5 Ultrafiltration

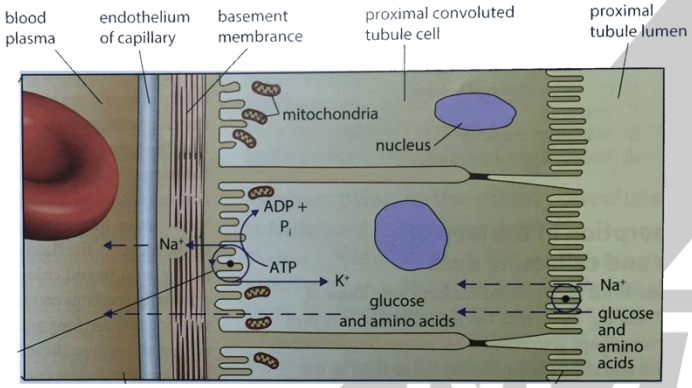
- Occurs in the glomerulus and bowman's capsule
- It is caused by the hydrostatic pressure that builds up in the glomerulus due to the afferent arteriole having wider diameter than the efferent arteriole
- This causes the water potential of the blood (glomerulus) to rise above the Bowman's capsule, hence water travels down its concentration gradient
- There is a 3 cell layer lining that separates the two:
  - Endothelium: one cell thick cell with many holes
  - Basement Membrane: make up inner lining of bowman's capsule
  - Podocytes: inner lining of bowman's capsule

- The endothelium & podocytes have large holes that allow substances to pass through it. However, basement membrane acts as a filter and stops larger molecules/cells from entering such as protein, RBCs and WBCs



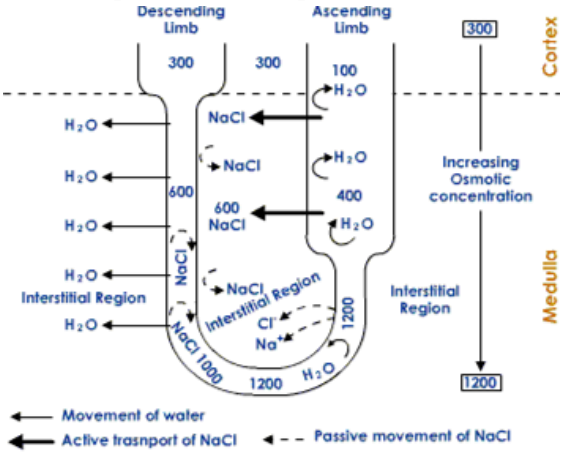

## 8.6 Selective Reabsorption

- The glomerular filtrate is almost identical to the plasmas concentration of substances except no plasma proteins
- Many of the substances however are needed to be kept in the body, so in the Proximal Convoluted Tubule (PCT) selectively reabsorbs back into the blood
- Adaptation of PCT cells:
  - Microvilli to increase surface area of inner surface
  - Many mitochondria to provide ATP for ($Na^+$–$K^+$) pump on outer membrane of cells
  - Co-transporter proteins in membrane facing lumen




- $Na^+$–$K^+$ pumps in the basal membrane cells use ATP pumping 3 $Na^+$ out and 2$K^+$ in.
- Basal membrane is folded to give a large surface area for many of these protein pumps
- Concentration of $Na^+$ decreases, so $Na^+$ passively moves into the cell from the lumen by a Co-transporter protein that brings along a molecule of glucose/amino acid
- This is considered to be a secondary active transport as energy was not used for pumping sodium into the PCR cell but has occurred as a result of active transport
- All of glucose, amino acids, vitamins and $Na^+$/$Cl^-$ are reabsorbed hence increasing water potential in filtrate, so water and urea are also reabsorbed but only partially

## 8.7 Reabsorption in Loop of Henle




1. $Na^+$ & $Cl^-$ are actively transported out of higher end of ascending limb, causing increase of conc. in tissue fluid
2. Water is therefore lost from the descending limb and $Na^+$ & $Cl^-$ ions diffuse in causing descending limb to become very concentrated as it reaches the bottom
3. $Na^+$ & $Cl^-$ diffuses out initially in the ascending limb and no water enters as ascending limb impermeable

**Distal Convoluted Tubule**

- First part functions the same way as ascending limb
- Second part functions the same way as collecting duct

**Collecting Duct**

- $Na^+$ actively pumped out into tissue fluid where they pass into the blood
- $K^+$, however is actively transported into the tubule
- The rate at which these two ions are moved into and out of nephron can be varied, regulating the ions in blood

## 8.8 Control of Blood Water Potential

- Osmoregulation: control of water potential in body fluids
- Specialised sensory cells (osmoreceptors) constantly monitor blood in the hypothalamus
- When a water potential decreases below a set point nerve impulses are sent to the posterior pituitary gland
- Stimulating release of antidiuretic hormone (ADH) that targets the collecting duct increasing reabsorption

**Decrease in blood water level**

4. ADH secreted and travels through blood until reaching receptor proteins on cell surface membrane of collecting duct cells
5. This activates enzyme inside cell & causes readymade vesicles that contain aquaporin fuse to membrane
6. This causes duct to become permeable to water hence water moves out down its conc. gradient

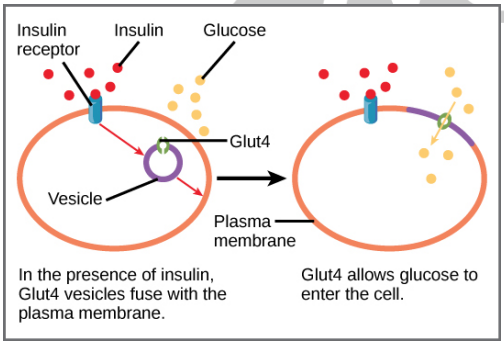
- Note: volume of urine decreases and become conc.

**Increase in blood water level**

- Osmoreceptors no longer stimulate ADH production, so aquaporins moved back into cytoplasm as vesicle, hence becoming impermeable again
- This process is very slow because ADH molecules take 15-20 mins to be broken down in the blood and another 15-20 mins for aquaporins to be removed

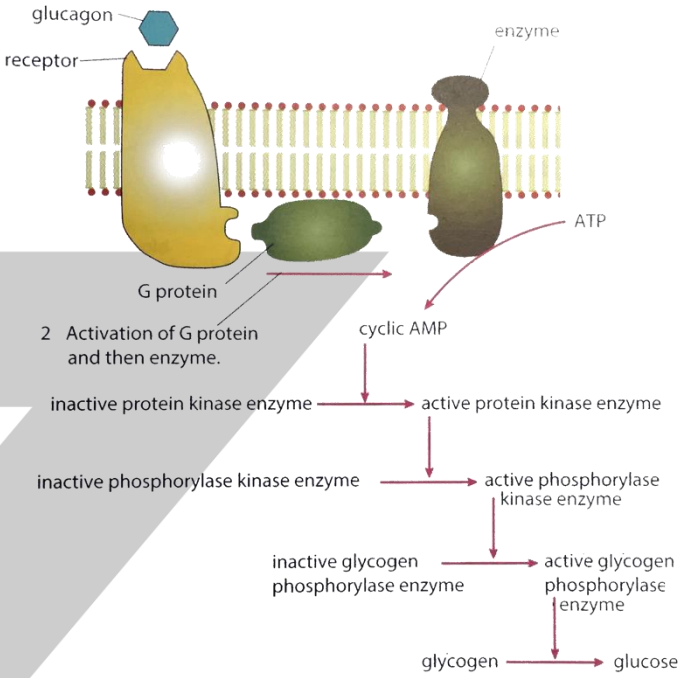
## 8.9 Control of Blood Glucose

- When glucose is in low concentration our cells may not have enough glucose for respiration, hence might not be able to carry out its normal function
- On the contrary, high concentrations can effect normal behaviour of cells as they may lose water due to the concentration gradient built (cells become flaccid)
- The homeostatic control is carried out in the pancreas by a tissue called the **islets of Langerhans** which consisting two types of cells:
  - $\alpha$ cells which secrete glucagon
  - $\beta$ cells which secrete insulin
- After a meal containing carbohydrates, glucose is digested and passed into the blood
- **When Blood glucose levels rise**
- The $\alpha$ and $\beta$ cells detect the change
  - $\alpha$ responds by stopping secretion of glycogen
  - $\beta$ responds by secreting insulin into the blood
- Insulin is a signalling molecule that targets the liver and muscle cells and can not pass through the membrane (as it's a protein) so it binds to a receptor
- This stimulates the cells to to increase rate of glucose absorption by making vesicles carrying glucose transporter proteins (GLUT) bind onto cell membrane




- Increases use of glucose in respiration
- Glycogenesis; condensing glucose molecules to glycogen
- **When blood glucose levels fall (or adrenaline level rise)**
  - $\alpha$ responds by secreting glycogen into the blood
  - $\beta$ responds by stopping secretion of insulin
- Glycogen binds on to a receptor which activates;
- G protein that in turn activates;
- Enzyme that catalyses conversion of ATP to cyclic AMP
- Cyclic AMP binds to kinase enzymes that activates other enzyme cascade reactions which finally catalyses the break down of glycogen to form glucose

## 8.10 Diabetes




- There are two forms of sugar diabetes:
  - Insulin dependant diabetes, Type1

The pancreas is incapable of secreting sufficient insulin, can be due to gene that codes for production, or because of attack on $\beta$ cells by own immune system.

  - Non insulin dependent diabetes, Type 2

Pancreas secretes insulin but liver and muscle cells do not respond properly.

## 8.11 Urine Analysis

- Much easier to collect than blood samples
- Urine tests can give early indications of health problems
  - Diabetes: presence of excessive glucose and ketones in urine, as blood glucose level rises above renal threshold and so not all reabsorbed
  - High blood pressure/kidney infection: presence of proteins as they are too large to be filtered out

## 8.12 Dipsticks and Biosensors

- **Dipsticks** are used to measure different factors such as: pH, glucose, ketones and proteins

- Glucose dipsticks contain **glucose oxidase** and **peroxidase**
- Glucose oxidase oxidised glucose to form gluconolactone and hydrogen peroxide
- Peroxidase catalyses reaction of hydrogen peroxide and chromogen forming a brown compound
- The colour formed is compared to a chart, the more glucose present, the darker the colour would be

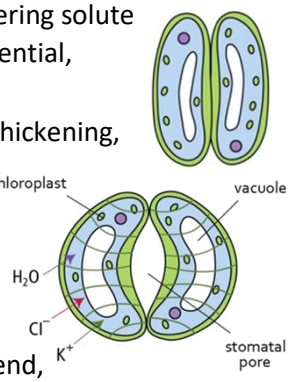
- **Biosensors** allow people with diabetes to monitor their blood glucose concentration much quicker than dipsticks
- They also contain glucose oxidase which catalyses the same reaction releasing $H^+$ so generating an electric current
- Current is detected and gives a reading within seconds
- The more the glucose present the greater is the reading


## *8.13 Homeostasis in Plants*

- Stomata has daily rhythms of opening and closing even if kept in constant light/dark
- Opening during day maintains inward diffusion of $CO_2$ and outward diffusion of $O_2$ and water vapour
- Closing during the night as it does not respire and conserves water
- Stomata open when:
  - Increase in light intensity
  - Low $CO_2$ concentrations
- Stomata close in:
  - Darkness
  - High $CO_2$ concentrations
  - Low humidity
  - High temperature
  - Water stress

**Opening and closing of stomata**

- **Opening** of stomata:
- ATP powered proton pumps actively move $H^+$ ions out of the guard cells
- This causes potassium channels to to open & move into the cell due to the **electrochemical gradient** produced
  - Electrochemical gradient is the combination of an electrical gradient caused by the release of $H^+$ ions and of a concentration gradient due to low levels of $K^+$
- Potassium ions enters the cell lowering solute potential and hence the water potential, causing water to enter the cell
- The stomata has uneven cell wall thickening, walls adjacent to pore is very tick, whereas the walls furthest from pore is thin
- so water when water enters the cells become turgid, inner cells is thicker so more difficult for it to bend, hence the cells on the outer end lengthen cause the guard cells to bend and open




- Stomata **closes** when hydrogen ion pumps stop and potassium ions leave the guard cells
- Water then leaves the cells and cause it to become flaccid and so close the stomata

**Abscisic acid and stomatal closure**

- ABA also known as the stress hormone causes the closure of stomata in difficult conditions within minutes
- It is synthesised by any cells in the plant that contain chloroplasts
- It is believed that ABA binds to receptors that inhibit the proton pumps and stimulate movement of $Ca^+$ ions into the cell which stimulate channel proteins to allow negatively charged ions to move in and potassium ions to move out

# 9. COORDINATION

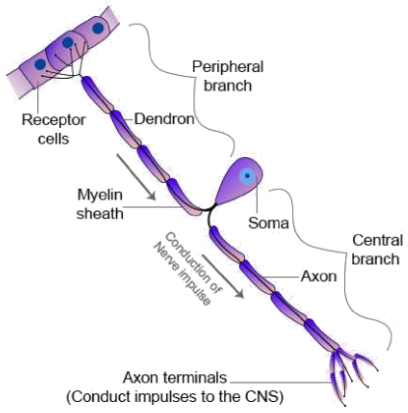
## *9.1 Types of Information Transfer*

| | Nervous System | Endocrine System |
|---|---|---|
| Form of transmission | Electrical impulses | Chemical messengers (Hormones) |
| Formed at | Sensory neurone generates impulse | Secretory gland |
| Travel in | Neurones | Blood (endocrine) |
| Speed | Instantaneous | Slow |
| Duration | Short-term | Long lasting |
| Energy | Large amount | Less required |

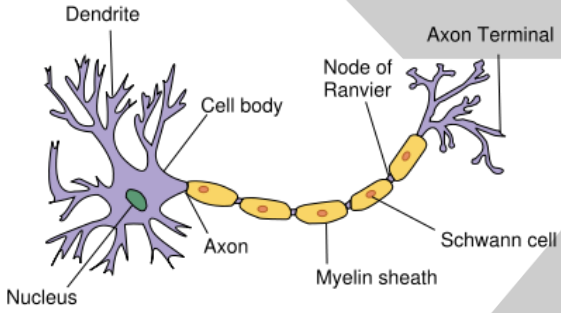
## *9.2 Neurones*

3 different types of neurones:

- **Sensory neurone:** Transmits impulses from receptor to CNS
  - Cell body near source of stimulus or swelling of spinal cord known as ganglion




- **Intermediate Neurone (Relay/Connector):** transmit impulse from sensory to motor neurone
  - Found entirely in CNS
- **Motor Neurone:** Transmit impulses from CNS to effector
  - Cell body lies within CNS and contains the nucleus
  - Dark specks in cytoplasm are rough ER regions




## 9.3 Reflex Arc

A **reflex arc** is the pathway along which impulses are transmitted from receptor to an effector without involving the 'conscious' regions of brain

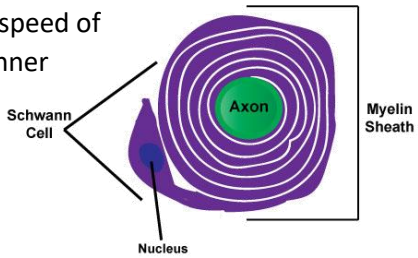
- Impulses travel from sensory to relay (not always) and finally to motor neurone
- Within the spinal cord impulses will also be passed onto other neurones which take it up to the brain whilst simultaneously passing through motor neurone
- Therefore effector acts before brain could process, hence this is a reflex reaction, which is fast and automatic and is useful in response to danger

## 9.4 Myelin

- About a third of axons on motor and sensory neurons are surrounded by thick dark rings called myelin which are made by specialised cells called **Schwann Cells**
- The Schwann cell (made of lipid and some proteins) wrap themselves around the axon enclosing it within many layers, the uncovered regions between these cells are called **Nodes of Ranvier**

**Speed of Conduction**

- Myelination causes speed of conduction to increase from $0.5ms^{-1}$ up to $100ms^{-1}$, this is because myelin stops depolarisation to occur
- Myelin also causes **salutatory conduction** which is when action potentials jump from one node to the next, this is about 50 times faster than unmyelinated axon
- **Diameter** also effects speed of transmission, with thinner axons there is greater resistance hence transmit slower



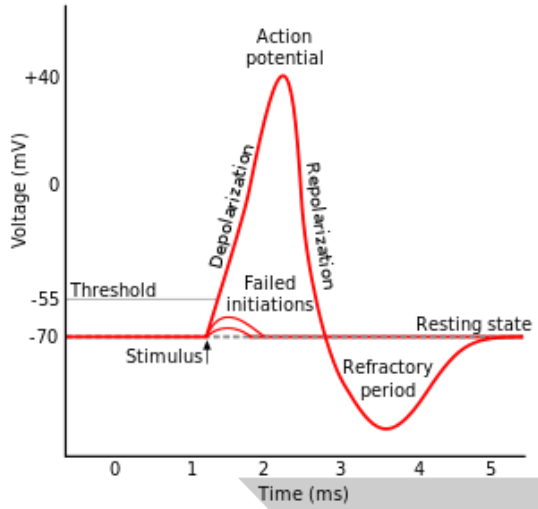

## 9.5 Transmission of Nerve Impulses

- Axons have a **resting potential** at which they are most of the time unless being **depolarised**
- Resting potential has a potential difference of about -70m$V$ compared to the outside
- Resting potential (negative nature) is achieved by:
  - Axon phospholipid bilayer impermeable to $K^+$/$Na^+$
  - Sodium-potassium pumps that constantly pump out $3Na^+$ ions and pumps in $2K^+$ each time
  - There are also separate $Na^+$ and $K^+$ channels that are open all times, and many more of $K^+$ channels, hence $K^+$ diffuses back out much faster than $Na^+$ diffuses in
  - Many large negatively charged molecules inside cell

**Action Potential**

- An initial stimulus causes the opening of some **voltage-gated** channels to open causing sodium ions to rush in due to the **electrochemical gradient**
- This causes the potential difference to become less negative and is called **depolarisation**, if this potential difference reaches -50m$V$ then all channels open and cause the inside to become +30m$V$: action potential
- Hence for an action potential to be produced the potential must pass the **threshold potential** of -50m$V$
  - This is known as the all-or-nothing law as the neurones either transmit impulse or do not
- After 1ms, all voltage-gated channels close & $K^+$ channels open causing them to diffuse out thus repolarising
- Axons have a **refractory period** after it has been polarised where it is unresponsive to new stimulations wand its consequences are:
  - Action potentials do not merge and so are discrete
  - There is a minimum time between action potentials occurring at one place on neurone

- Length of refractory period determines max frequency at which impulses are transmitted




**How action potentials carry information**

- Action potentials do not change in size whether large or small stimulus & has constant peak value of +30m$V$
- The brain receives action potential from **specific position** of neurones and interprets its **nature** such as heat, light, touch and so on

**Strength** of stimulus

- The brain interprets this from the **frequency** of the action potential, stronger stimuli have larger frequency
- Also strong stimuli cause more neurones to be stimulated hence the **number** of neurones carrying action potential can tell us about the strength

## 9.6 Receptors

- A receptor cell is one that responds to stimulus by converting energy from one form to electrical impulse, initiating an action potential (acts as a transducer)
- Receptor cells are often found in sense organs and are specialised cells which detect specific type of stimulus

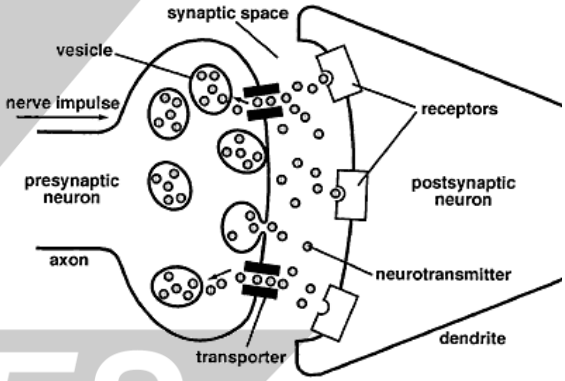
**Tongue**

- The tongue is covered in many papillae, each papillae has many taste buds over its surface and within each taste bud lies around 50-100 **chemoreceptors**
- Ions diffuse through highly selective channels and causes depolarisation of the membrane: **receptor potential**
- If sufficient enough stimulation produced voltage-gated calcium ions open, calcium then enters and causes excretion of neurotransmitter vesicles
- This causes action potential to form in the sensory neurone and eventually reaching the cortex brain

## 9.7 Synapses

- Region where two synapses meet, there is a small gap called the **synaptic cleft**
- The synaptic cleft contains transmitter substances (neurotransmitters) that which stimulate next neurone
- How action potentials are transmitted:
  - Action potential arrives at presynaptic knob, causing $Ca^{2+}$ voltage gated channels to open
  - $Ca^{2+}$ ions cause exocytosis of Acetylcholine (ACh) vesicles (synapses that have acetylcholine are called **cholinergic synapses**)
  - ACh moves to presynaptic knob temporarily binding to the **receptor proteins** that have complimentary shape
  - This causes $Na^{+}$ (chemical) channels in post synoptic knob to open, $Na^{+}$ enter and cause depolarisation
  - Ach is then recycled by enzyme **acetylcholinesterase** which breaks the it into acetate and choline which then recombined in the presynaptic knob

Note: If ACh is not broken down the $Na^{+}$ channels will remain open so neurone will be permanently depolarised

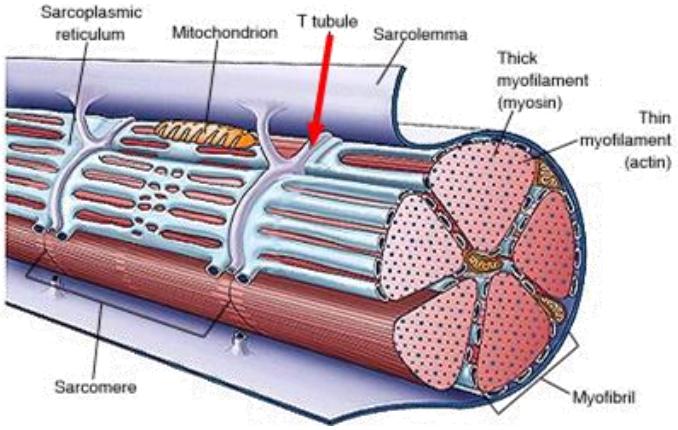



**Role of synapses:**

1. Ensures one-way transmission
2. Decreases the overload of information in the brain
3. Involved in memory and learning
4. Interconnection of nerve pathways: sensory and relay have many dendrite so can cause many more neurones to be activated by just one receptor cell

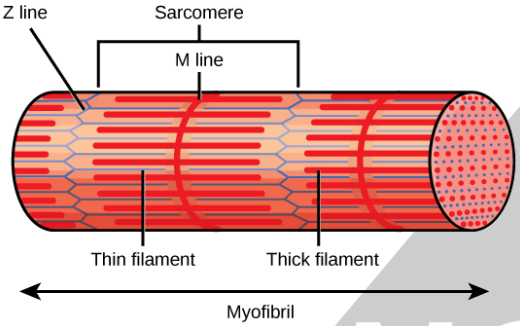
## 9.8 Muscle Contraction

- Striated muscle is multinucleate (**syncytium**) and is organised into parallel bundles of myofibrils that are attached to the skeleton which is controlled by neurones



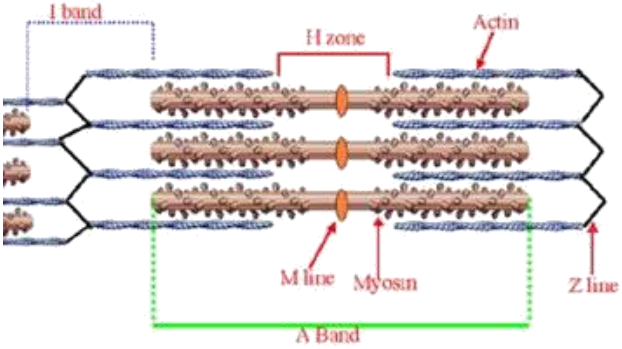

- The **sarcolemma** (cell surface membrane) splits into many infoldings called T-tubules
- The cytoplasm is called **sarcoplasm** and contains many mitochondria that generate the ATP required for muscle contraction
- The endoplasmic reticulum is called **sarcoplasmic reticulum(SR)**, they have many protein pumps that transport calcium ions into the cisternae of SR

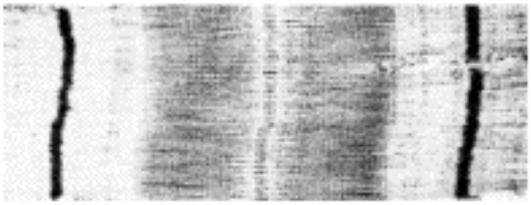
## *9.9 Structure of the Myofibrils*




- Myofibril itself is made up of smaller components of thick and thin filaments

  Thin → **actin** thick → **myosin**
- The Z line is where the actin filaments are attached to
- The M line does the same for myosin filaments
- Sarcomere is the part of myofibril between two Z lines



- The darker parts in the centre is the region of overlap of actin and myosin which is known as **A bands**
- The white area between these dark bands is the region where only myosin is present is known as **H band**
- The white area next to the thick black line (Z line) is the region where only actin is present and is called **I band**

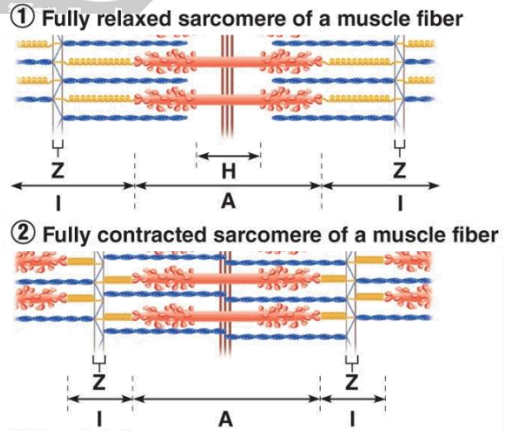
## *9.10 How muscles contract*

- Muscles movement is caused by contracting and causing Z discs to pull closer together by a process of sliding
- The energy comes from the ATP in myosin heads which also contain ATPase

**Process from stimulation**

- Sarcolemma is depolarised by an incoming action potential which spreads along membrane and T-tubule
- Calcium ions are released from sarcoplasmic reticulum and bind to troponin and so causing it to change shape
- This intern causes tropomyosin proteins to move to a different position exposing the binding site for myosin
- Myosin binds with this site forming cross-bridges
- Myosin heads tilt pulling actin filaments (power stroke) towards centre of sarcomere
- The heads hydrolyse the ATP molecules, providing enough energy for heads to let go of actin and return to original position and bind again to exposed actin site

- This process continues as long as binding sites are open and ATP is in excess




- During contraction the A band is unaffected however both H and I bands decrease in length

**Providing for muscle contraction**

- ATP can be provided from the small quantity of ATP found in the muscle by respiration and lactic formation
- ATP is used faster than it can be supplied by respiration
- Phosphocreatine allows regeneration of ATP without respiration
- Another process is to use **creatine phosphate**

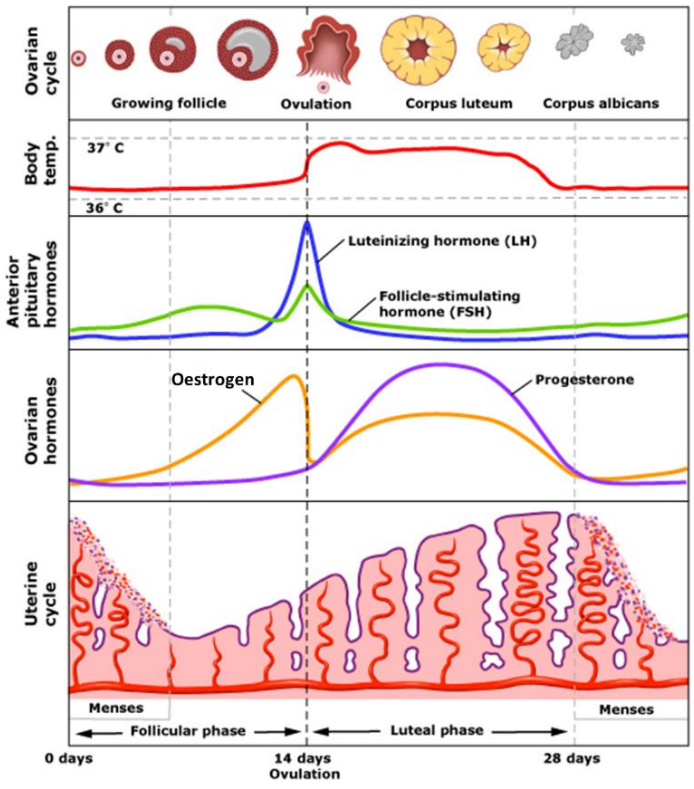
creatine phosphate + ADP → creatine + ATP

## *9.11 Hormonal Communication*

- Hormones are made in endocrine glands and are secreted into the blood (they are ductless)
- There are water soluble hormones that cannot pass into the cell so bind to receptors, however there are lipid soluble hormones which pass through cell membrane

**Hormonal control in menstrual cycle**

- The menstrual cycle is coordinated by the anterior pituitary gland and by the ovaries
- The anterior pituitary gland secretes **follicle stimulating hormone** (FSH) and **luteinising hormone** (LH)
- The **corpus luteum** (follicle after releasing gamete) secretes both **oestrogen** (stimulate endometrium to grow, thicken and develop numerous blood capillaries) and **progesterone** (to maintain the uterus lining)




- FSH and LH are in relatively high concentrations during menstruation and so cause one follicle to mature
- The presence of FSH and LH stimulates oestrogen to be produced by the cells surrounding the follicle
- Oestrogen however, has a negative feedback on FSH and LH so their concentrations decrease
- When oestrogen reaches a level two to four times initial value, it stimulates a serge of LH and FSH causing the graffian follicle to burst and ovulation occurs
- The corpus luteum is now formed and so oestrogen and progesterone are released, progesterone also inhibits secretion of FSH and LH so that no more follicles develop
- Corpus luteum begins to degenerate and so decrease in progesterone causing menstruation

**IVF**

- Women are given drugs to suppress their ovulation and then treated with hormones for two weeks after so that:
  - Superovulation takes place and more than one follicle matures at the same time
  - Also prepares uterus for implantation

Process of IVF

- oocytes are collected from mature follicles in the ovaries, they are then kept in a culture medium and mixed with sperm. Left for 3 days during which zygotes divide to form embryos, which are then placed into the mother's endometrium.

**Birth Control**

- Birth control pills can contain progesterone only or both progesterone and oestrogen (combined)
- The **progesterone pill** may not prevent ovulation to occur but they reduce the ability of sperm to reach the egg cell by increasing mucus levels in the cervix
- The **combined pill** similar to the progesterone pill where they must take the pill everyday for contraception to be effective as missing a single day could cause ovulation
- The combined pill supresses secretion of FSH and LH to a level where ovulation would not occur due to the negative feedback from high levels of progesterone
- During the 7 days of menstruation pills or not taken so that progesterone levels would fall and cause menstruation, reassuring that woman is not pregnant
- The combined pill can also be given by means of skin patch, injection and implanting under the skin

## 9.12 Electrical Communication in Plants

**Venus fly trap:**

- The venous fly trap is a carnivorous plant that obtains its supply of nitrogen compounds by digesting small insects
- The leaves can attract prays by releasing nectar
- Each leaf also has three stiff sensory hairs that respond to being deflected
- Outer edges have stiff hairs that trap the insect inside and has gaps between to allow smaller insects to escape as it would not be worth the energy used up

**Action of shutting the trap**

- When an insect lands onto the leaf and touches the hairs this causes action potentials to be generated
- If another hair is stimulated in the next 20-35 seconds, the leaf shuts in about 0.3 seconds, however if not then action potential stops and first movement of hair is ignored (saving energy as it could only be a rain drop)
- $H^+$ ions are pumped into the cell walls
- Calcium pepctate 'glue' in the cell wall dissolves
- $Ca^{2+}$ enters the hinge cells causing water to enter by osmosis hence expanding the hinge cells
- Lobes of the leaves flip from convex to concave rapidly
- Further deflection of hairs causes calcium ions to causing exocytosis of vesicles containing enzymes for digestion

## 9.13 Chemical Communication in Plants

- Two types of plant growth regulators
  - Auxins: influence elongation of roots and shoots
  - Gibberellins: seed germination and stem elongation

**Auxins**

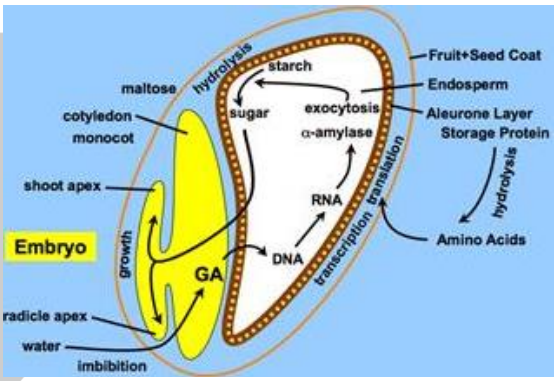
- Plants make several chemicals known as auxins, of which the main one is IAA
- Auxins are synthesised in growing tips/meristems
- Auxins inhibits growth of side shoot
- It is transported up or down by active transport from cell to cell
- It also moves by mass flow in the phloem
- Auxins bind to a protein receptor which stimulates ATPase to pump in $H^+$ into cell walls causing a loosening of the bonds, water is absorbed by osmosis and pressure potential causes the wall to stretch hence cell elongates
- Auxins also inhibit lateral growth so that cells grow taller

**Gibberellins and stem elongation**

- The gene *Le* causes the synthesis of the last enzyme that produces active form of gibberellin $GA_1$
- Active gibberellin stimulates cell division and cell elongation in stem cells causing the plant to grow tall
- Plants that are homozygous and have the recessive allele *le* that produces non-functional enzyme hence don't produce active gibberellin and so are genetically dwarf
- Applying active gibberellin to plants that would remain short can stimulate them to grow tall

**Gibberellins and seed germination**

- Seeds are in a state of dormancy; this allows it to survive through cold winters and is only activated when enough water is present and absorbed




- Absorption of water stimulates embryo to produce gibberellins
- Gibberellin causes breakdown of DELLA proteins that inhibit transcription, hence mRNA coding for amylase is transcribed in the aleuronic layer
- Amylase mobilises energy reserves by hydrolysing starch to maltose in the endosperm
- Maltose molecules are then converted into glucose and respired to provide energy for growth

# 10. Genetic Engineering

**Recombinant DNA (rDNA):** is DNA made by joining pieces from two or more different sources

- Steps essential for producing genetically modified organism:
  - Identify Gene
    - Cut from DNA
    - Reverse transcription of mRNA
    - Synthesised from nucleotides
  - Make multiple copies by PCR
  - Insert gene into vector for delivering it: plasmids, viruses, liposomes
  - Cells with the new gene are identified and cloned

## 10.1 Identifying the Gene

*Method 1:*

**Restriction Endonuclease:** enzyme that come from bacteria which can breakdown DNA of invading virus

- 'Endonucleases' as they cut the DNA from the sugar phosphate backbone
- These enzymes bind to specific target site on the DNA molecule where there is specific base sequence
- Usually they bind to palindromic sites (site that is same in both directions) e.g. GGATCC
- Can form cut and form either
  - Blunt ends: straight cut across sugar phosphate
  - Sticky ends: short unpaired staggered ends

*Method 2:*

- As mentioned above the using reverse transcriptase enzyme we could obtain a cDNA strand (same as DNA)
- This process, however requires you to find the mRNA molecules in a cell cytoplasm

*Method 3:*

- Since proteins have now been sequenced, we can now synthesise DNA artificially from nucleotides

## 10.2 Inserting Gene into Vector

**Plasmids:** small, circular, double-stranded DNA that is used as a type of vector, which gets new genes into a recipient cell

- To obtain plasmids, bacteria are treated with enzymes to break their cell walls and are then centrifuged
- Plasmid is then cut open using same restriction enzyme used for the DNA so that sticky ends are complimentary
- Plasmid and DNA are mixed together and with **DNA ligase** the sugar phosphate backbone is fixed together forming rDNA

Properties of plasmids allowing them to be used as vector:

- Low molecular mass; can be taken up by bacteria easily
- One or more marker genes; allowing cells that take up plasmid to be identified
- An origin of replication so that they can be copied

**nserting and identifying bacteria with rDNA**

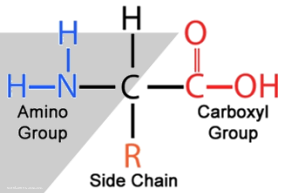
- Bacteria are put into solution with high $Ca^{2+}$ conc., they are cooled then given heat shock to increase chances of plasmid passing through cell membrane
- Only about 1% take up the plasmid and are said to be transformed
- In the past we used to use agar plates containing an antibiotic to identify the bacterium with the plasmid, but this had caused bacteria to grow resistant strains
- Now we use a gene that codes for the production of an enzyme (along with a promoter) that makes green fluorescent protein which fluoresces in u.v light which is an easier method to identify bacteria and also more economical than using antibiotic resistance genes

**Promoters**

- Promoters allow RNA polymerase to bind to DNA start transcription of the template strand
- Promoters used to stop all genes from being transcribed & so waste less energy on unwanted proteins

## 10.3 Electrophoresis of Proteins

- Proteins are made up of amino acids and the charges on these amino acids depend on R groups present and pH




- In acidic pH, the $NH_2$ groups (bases) gain a proton and so become $NH_3^+$, hence net charge becomes positive ∴ moves towards cathode (-ve)
- In basic pH, the COOH groups (acids) lose their protons and so becomes $COO^-$, hence net charge becomes negative ∴ moves towards anode (+ve)
- In neutral conditions the $NH_3^+$ is cancelled by the $COO^-$ so it depends solely on the R group
- E.g. haemoglobin in sickle cells contain one less charged R group than in normal cell, hence when separated sickle celled moves less than that of normal

## 10.4 Electrophoresis of DNA

- Fragments of DNA move towards the anode (+ve) as it has negatively charged phosphate groups
- **Genetic profiling (fingerprinting):** sequencing a length of DNA of one organism and comparing it to another by looking at the 'variable number tandem repeats' (VNTRs)
- **Steps in electrophoresis:**
  - DNA extracted from anything that contains cells such as, root of hair, blood splatter, saliva and so on
  - PCR is used to increase number of DNA
  - DNA cut into fragments using restriction endonuclease
  - DNA is place on agarose gel and current is applied
  - Fragments travel towards anode, shorter fragments traveling further/faster, than longer ones
  - Due to fluorescently stained probes you could easily visualize the DNA by shining UV light on it

## 10.5 Polymerase Chain Reaction (PCR)

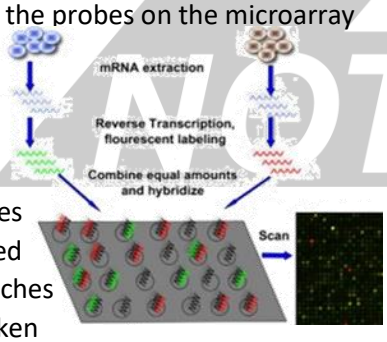
- Is a method for rapid production of a particular fragment of DNA to produce a very large number of copies
- **Steps involved in PCR**
  - DNA is denatured by heating to $95^oC$ temperature and double helix splits into two strands
  - **Primer** annealed onto DNA after cooling to about $65^oC$ (primer is short sequence of complimentary DNA)
  - **DNA Polymerase** latches onto primer at $72^oC$ and continues to add free nucleotides along rest of DNA
  - This process is then repeated many times, at each time doubling amount of DNA produced (exponential inc.)
- DNA polymerase used is $Taq$ polymerase because:
  - Is not easily destroyed by denaturing
  - High optimum temperature: so temp. does not have to be below ($65^oC$), hence more efficient

## 10.6 Microarrays

- Tool to identify the genes present in an organism's genome and which genes are being expressed
- It could also be used to compare genes present in two different species

**Process:**

- DNA is collected from each species and cut up into different fragments and denatured to give lengths of single-stranded DNA
- DNAs are labelled with fluorescent and mixed together allowing to hybridise with the probes on the microarray
- DNA that does not bind to the microarray is washed off
- Microarray is inspected using u.v light, dark patches show that DNA was washed away, and fluorescent patches show hybridisation has taken place (some patches can have both fluorescents those are areas where both DNA have exact same sequence)




To Identify the genes present that are being expressed:

- The mRNA is reverse transcripted to form cDNA
- PCR can be done if cDNA is in low quantity
- Now the same process as above can be used
- The fluorescence in the microarray indicates that those genes were being transcribed and their intensities indicate the activity of each gene

## 10.7 Bioinformatics

**Bioinformatics** is the collection, processing and analysing of biological information & data using computer software

- Bioinformatics combines biological data with computer technology and makes links
- Databases hold gene sequences, complete genomes, amino acid sequences and protein structures
- Gene sequencing is the order of base pairs in sections of DNA and genomes of many species have been published

e.g.

- Researches can use these databases to find similarities between the sequence of what they are studying and of saved sequences in the databases
- Sequences can be matched and degree of similarity calculated, this can show if there is common ancestry

## 10.8 Producing Human Proteins by GE

- Insulin
- Factor $VIII$ - blood clotting protein
- Thyroid stimulating hormone
- Human growth hormone

- The general advantages of producing the proteins by genetic engineering is that:
  - Low nutritional requirement
  - Large volume of product produced
  - Production facilities do not require much space and so can take place all around the world
  - No risk of infection e.g. HIV from blood donation

**Insulin**

- In the past diabetics were treated with insulin extracted from pancreases of pigs or cattle
- Gene technology made it possible to synthetically make our own insulin
- So the advantage is that we now have a reliable supply of insulin available to the increasing demand

Method of insulin production:

- mRNA from human pancreatic $\beta$ cells are extracted
- mRNA is incubated with reverse transcriptase producing single stranded cDNA
- DNA polymerase used to convert into double strand
- Insulin gene is then placed into a plasmid to transform the bacterium
- The bacteria can now produce insulin, so they are grown in large fermenters and insulin is extracted

Reason why mRNA is more suitable than DNA extraction:
- mRNA is only from gene coding for insulin, whereas DNA has all genes and so you must locate and extract gene
- Restriction enzyme would be needed for DNA extraction
- Large number of mRNA that code for insulin

**Factor *VIII***
- This is a protein that is essential for blood clotting, people who do not have it are said to be **haemophilic**

Method of Factor *VIII* production:
- Human gene inserted into hamster kidney and ovary cells
- They are then cultured in fermenters, and so they produce the protein
- Protein is extracted, purified and regularly injected to patients

## 10.9 Genetic Screening and its Ethics

**Genetic screening** is the analysis of a person's DNA to check for the presence of a particular allele
- Adult woman can screen for gene *Barca-1* and *Barca-2* which increases chances of breast cancer
- At the 8 cell stage during an IVF, one cell can be removed and checked for diseases, if embryo healthy then implanted if not then discarded
- Therapeutic abortion is; terminating pregnancies for medical reasons and having advice from professional
- Parents decide to have abortions even if the defect is minor and child could have normal life
- Parents also abort due to the sex of their child
- People that are diseased and check screen for it may never develop the disease but would have to live with the fear of knowing it can start at anytime

## 10.10 Types of Vectors

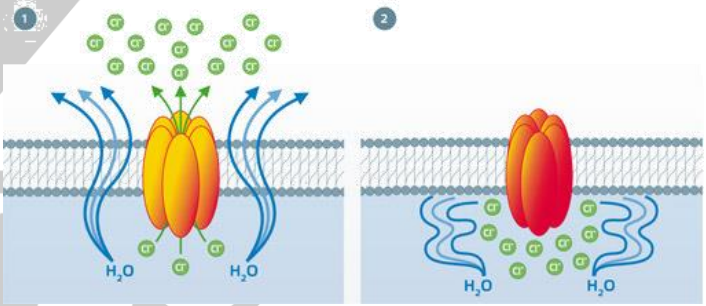
1. Viruses
2. Naked DNA
3. Liposomes (spheres of phospholipid)

**Viruses**
- **Retroviruses** insert their genes into host randomly, so they may insert it within a gene, or even worse into the regulatory gene and so can cause cancer
- **Lentiviruses** also insert genes randomly however, they can be modified to inactivate replication

## 10.11 Diseases and Gene Therapy

- **SCID** is the inability to produce the enzyme adenosine deaminase (ADA) hence causes immune system to be crippled, and sufferers usually die in infancy from common infections
- **Inherited eye disease** this is a form of hereditary blindness in which retinal cells die off gradually from an early age

**Cystic Fibrosis**
- Cystic fibrosis is a recessive allele that codes for a transport protein called CFTR, causing the production of abnormal thick mucus that is difficult to be removed
- Other body parts such as pancreatic duct can become blocked as well as reproductive ducts causing infertility
- CFTR effects the lungs:
  - Due to mucus not moving effectively by cilia, cilia trap bacteria and so causing infections
  - Reduces gaseous exchange, by making it a longer diffusion pathway
  - Causes difficulty in breathing
  - Lungs may get scarred
- The CFTR gene codes for a faulty version of a transport protein that allows chloride ions to pass out of cell




- Chloride ions are essential to be transported out so that they cause concentration gradient outside, hence causing water to move out of cells by osmosis
- The water mixes with the mucus making it easy for removal by the sweeping movement of cilia

**Gene Therapy**
- Is the altering of a genotype and inserting the normal allele into the appropriate cells using a vector, producing a functional recombinant DNA
- The CFTR gene is usually the cause of a mutation of a deletion of 3 bases, so in theory inserting normal dominant allele would transcribe the normal protein

- However, problems occur in practical situation such as:
  - Short natural lifespan; effects only last for a few days
  - Low uptake by target cells
  - Only target lung cells at this time
  - Side effects such as infections caused by the virus
- The advantages on the other hand are:
  - No physiotherapy/antibiotics are needed
  - Less time consuming than other types of treatments

## 10.12 Genetically Modified Plants

**Herbicide resistant crops**

- Growing herbicide resistant crops allows you to spray herbicide after seed has germinated, this kills weeds that would otherwise compete for space, light, water and ETC
- This increases the yield of crop however; it has disadvantages also such as:
  - Genetically modified plants become agricultural weeds
  - Pollen will transfer into the wild and producing offspring's that are invasive weeds
  - Herbicide resistant weeds will evolve due to the usage of same herbicide and so mutate

**Insect resistant crops**

- This is another important development that allows plants to be protected against attack by insects
- Again crop yield increase however its disadvantages are:
  - Evolution of resistant insect's pests

**Golden Rice**

- Golden rice is meant to be healthier than white rice by having more of Vitamin A, which its deficiency can cause blindness and the immune syndrome that in turn causes a high level of mortality in children in developing countries
- Pro-vitamin A carotenoids are present in the aleuronic layer of normal rice grains however; this layer is usually removed so that it does not go rancid quickly
- Therefore, projects to produce rice that contain carotene in the endosperm were undertaken producing genetically modified golden rice

Disadvantages to growing Golden Rice would be:

- GM seed could be difficult for farmers in developing countries to obtain
- High cost of buying GM seed, so also expensive for people to buy
- May not grow well in all conditions
- Might reduce efforts to relieve poverty

## 10.13 Social Implications of Using GM Organisms in Food Production

- Modified crop plants can become agricultural weeds
- Introduced genes may be transferred by pollen to wild offspring and so become more invasive
- Can be transferred by pollen to organic certified farms
- Hazard to humans as they can produce allergies
- The herbicide can leave toxic residue on the crop
- Growers need to buy seeds each season which is expensive
- Can lose traditional varieties with their desirable background genes, hence would have to make programmes of growing and harvesting them. Also forcing us to setup seed bank to preserve them

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