

SUB-STRAND 1.1: CELLULAR ORGANISATION

ACHIEVEMENT INDICATORS

At the end of this sub-strand, students should be able to:

- ✓ Use the recommended procedures to correctly prepare a wet mount.
- ✓ Estimate and calculate the size and the number of cells observed at different powers of magnification.
- ✓ Define and describe the features of prokaryotes and eukaryotes.
- ✓ Identify, name and describe the stages of development from zygote to embryo.

BI 12.1.1.1 MICROSCOPES

Microscope (Greek: micro=small; scope=look/see) is one of the powerful tools used in Biology. It enables us to see specimen that are too small to be seen with the naked eye.

Specimen – is the object/ material observed under the microscope.

Power of Microscopes

1. **Magnify**- make tiny specimen appear big.
2. **Resolve**- ability to differentiate between two or more things that normally appear as one when seen with the naked eye.

The timeline provided below shows how microscope got invented and advanced.

History	
 14th century – The art of grinding lenses is developed in Italy and spectacles are made to improve eyesight. 1590 – Dutch lens grinders Hans and Zacharias Janssen make the first microscope by placing two lenses in a tube. 1667 – Robert Hooke studies various object with his microscope and publishes his results in Micrographia. Among his work were a description of cork and its ability to float in water. 1675 – Anton van Leeuwenhoek uses a simple microscope with only one lens to look at blood, insects and many other objects. He was first to describe cells and bacteria, seen through his very small microscopes with, for his time, extremely good lenses. 18th century – Several technical innovations make microscopes better and easier to handle, which leads to microscopy becoming more and more popular among scientists. An important discovery is that lenses combining two types of glass could reduce the chromatic effect, with its disturbing halos resulting from differences in refraction of light. 1830 – Joseph Jackson Lister reduces the problem with spherical aberration by showing that several weak lenses used together at certain distances gave good magnification without blurring the image. 1878 – Ernst Abbe formulates a mathematical theory correlating resolution to the wavelength of light. Abbe's formula makes calculations of maximum resolution in microscopes possible. 1903 – Richard Zsigmondy develops the ultramicroscope and is able to study objects below the wavelength of light. The Nobel Prize in Chemistry 1925 1932 – Frits Zernike invents the phase-contrast microscope that allows the study of colourless and transparent biological materials. The Nobel Prize in Physics 1953 1938 – Ernst Ruska develops the electron microscope. The ability to use electrons in microscopy greatly improves the resolution and greatly expands the borders of exploration. The Nobel Prize in Physics 1986 1981 – Gerd Binnig and Heinrich Rohrer invent the scanning tunnelling microscope that gives three-dimensional images of objects down to the atomic level. The Nobel Prize in Physics 1986 »	14th century – The art of grinding lenses is developed in Italy and spectacles are made to improve eyesight. 1590 – Dutch lens grinders Hans and Zacharias Janssen make the first microscope by placing two lenses in a tube. 1667 – Robert Hooke studies various object with his microscope and publishes his results in Micrographia. Among his work were a description of cork and its ability to float in water. 1675 – Anton van Leeuwenhoek uses a simple microscope with only one lens to look at blood, insects and many other objects. He was first to describe cells and bacteria, seen through his very small microscopes with, for his time, extremely good lenses. 18th century – Several technical innovations make microscopes better and easier to handle, which leads to microscopy becoming more and more popular among scientists. An important discovery is that lenses combining two types of glass could reduce the chromatic effect, with its disturbing halos resulting from differences in refraction of light. 1830 – Joseph Jackson Lister reduces the problem with spherical aberration by showing that several weak lenses used together at certain distances gave good magnification without blurring the image. 1878 – Ernst Abbe formulates a mathematical theory correlating resolution to the wavelength of light. Abbe's formula makes calculations of maximum resolution in microscopes possible. 1903 – Richard Zsigmondy develops the ultramicroscope and is able to study objects below the wavelength of light. The Nobel Prize in Chemistry 1925 1932 – Frits Zernike invents the phase-contrast microscope that allows the study of colourless and transparent biological materials. The Nobel Prize in Physics 1953 1938 – Ernst Ruska develops the electron microscope. The ability to use electrons in microscopy greatly improves the resolution and greatly expands the borders of exploration. The Nobel Prize in Physics 1986 1981 – Gerd Binnig and Heinrich Rohrer invent the scanning tunnelling microscope that gives three-dimensional images of objects down to the atomic level. The Nobel Prize in Physics 1986 »

Source: <http://www.history-of-the-microscope.org/history-of-the-microscope-who-invented-the-microscope.php>

Types of Microscopes

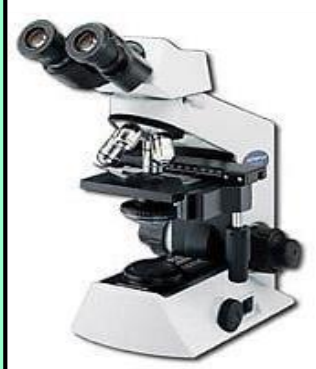
1. **Optical Microscope** (uses light) – Normal microscopes
 - (i) Simple Microscope (one lens)
 - (ii) Compound Microscope (many lenses)
 - (iii) Dissection/Stereo Microscope (3D image)

NOTE:

The commonly used microscopes in schools and universities are optical microscopes:

(1) Compound and (2) Dissecting

1. Compound Microscope



Source: www.deanza.edu

2. Dissecting Microscope

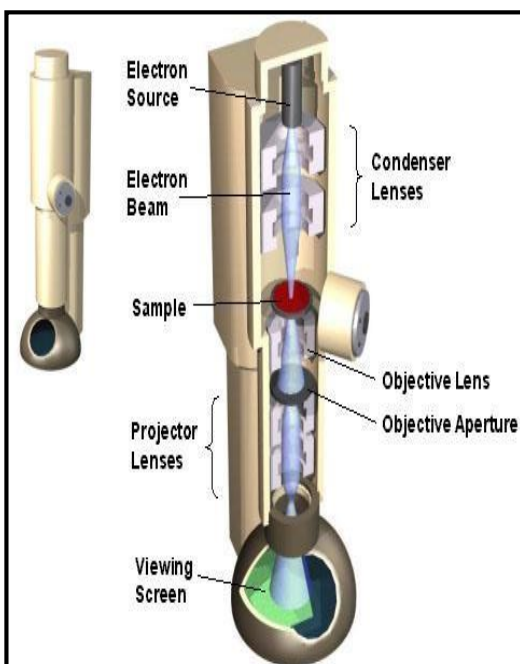


Source: www.bmercl.uh.edu

2. **Electron Microscope** (uses electrons) – Advanced microscopes

(i) Transmission Electron Microscope (TEM)

- ❖ First type of electron microscopy.
- ❖ High voltage electron beam emitted by a cathode and formed by magnetic lenses.
- ❖ Ultra-thin specimen required to allow the electrons to pass through.
- ❖ Image produced is 2D black and white image.



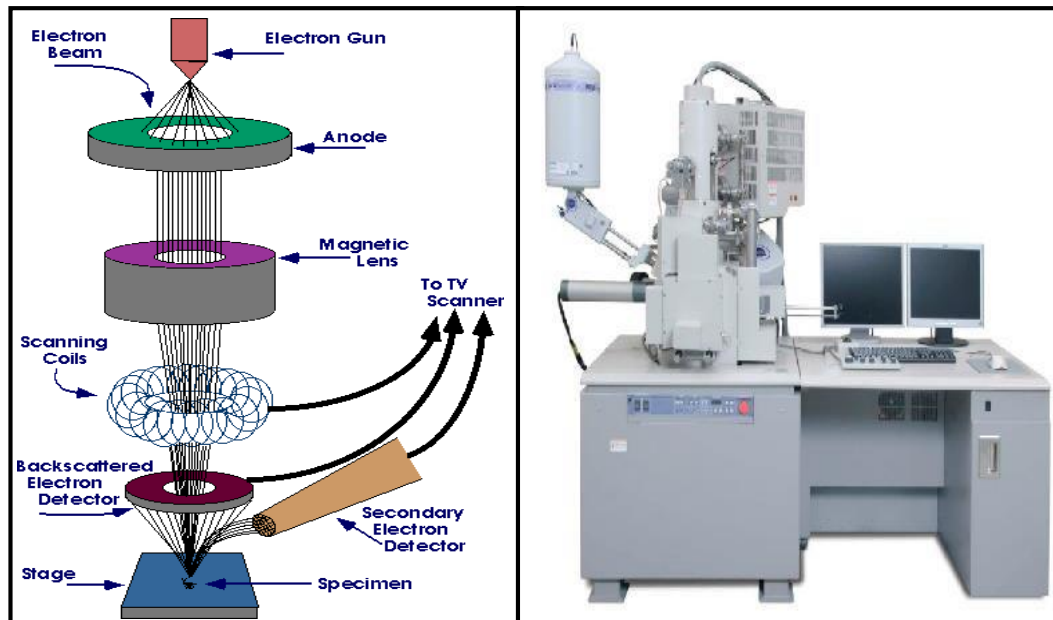
Source: www.barrett-group.mcgill.ca



Source: www.news-medical.net

(ii) Scanning Electron Microscope (SEM)

- ❖ In TEM, the electrons in the primary beam are transmitted through the specimen but in the Scanning Electron Microscope (SEM) images are produced from the secondary electrons which are emitted from the surface due to excitation by the primary electron beam.
- ❖ The electron beam is scanned across the surface of the sample in a raster pattern, with detectors building up an image by mapping the detected signals with beam position.



Source: www.purdue.edu

Source: www.gallery.asiaforest.org

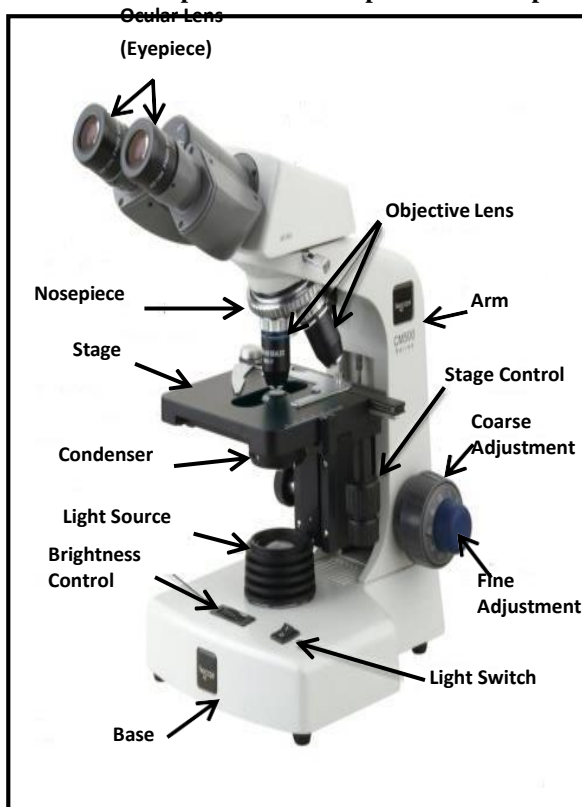
(iii) Scanning Transmission Electron Microscope (STEM)

- ❖ STEM combines the capabilities of both an SEM and a TEM.
- ❖ The electron beam is transmitted across the sample to create an image (TEM) while it also scans a small region on the sample (SEM).

(iv) Reflection Electron Microscope (REM)

- ❖ Uses scattered high-energy electrons falling on a surface at glancing angles to generate an image of the surface.
- ❖ This type of microscope usually has two magnification characteristics: magnification in the electron beam incidence plane and magnification in the plane perpendicular to the incidence plane

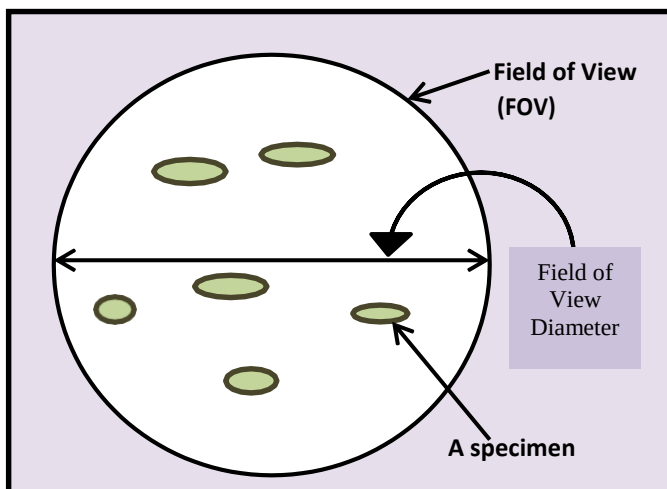
Parts of a Compound Microscope and the Respective Functions



Source: www.microscopemaster.com

- **Ocular Lens (Eyepiece)** - Lens through which specimen is viewed.
- **Objective Lens** - Lens close to the specimen; magnifies the specimen together with ocular lens.
- **Arm**- Connects the body tube to the base of the microscope; for holding microscope.
- **Stage**- platform where specimen is placed.
- **Stage Control**- moves the stage sideways, right and left.
- **Coarse Adjustment**- brings the specimen into focus by moving the tube or stage up/down bigger distance.
- **Fine Adjustment**- Fine tunes the focus and increases the detail of the specimen.
- **Light Switch**- switches the light on/off.
- **Base**- The base supports the microscope and it's where the light is located.
- **Brightness Control**-allows the user to control the amount of light produced by the Light Source.
- **Light Source**- provides light.
- **Condenser**- Gathers and focuses light from the illuminator onto the specimen being viewed.
- **Nosepiece** - Rotates to allow the viewer to select different objective lenses.

View of Specimens When Seen with a Microscope



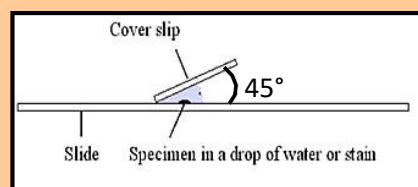
Approximate Diameter of the FOV (Eyepiece Lens: 10X)

Objective Lens	Total Magnification	Diameter (mm)
4X	40X	4.5
10X	100X	1.8
40X	400X	0.45
100X	1000X	0.18

Note: These are approximate values; the microscopes can be calibrated to check the actual diameter of field of view.

Steps for Preparing Wet Mounts

1. On a clean slide place a drop of water or the required stain.
2. In that drop, place the specimen. (Place a thin slice of the specimen if it is too big)
3. Lower a cover-slip at an angle of 45° to avoid trapping of air bubbles.
Note: If there is excess water in the wet mount, place a piece of tissue paper near the edge of the cover-slip for it to draw and absorb water. If there is too little water; using a dropper add some more water near the edge of the cover-slip.
4. Observe the wet mount under the microscope.



Focussing the Wet Mount under the Microscope for Observation

1. Place the microscope on the bench-top. (If the microscope has its own **light source**, then switch on the light; if it doesn't then place the microscope near a well illuminated area)
2. Rotate the **nosepiece** so that the lowest **objective lens** is in position. (Usually the lowest objective power is 4X)
3. Place the wet mount on the **stage** and secure it with the stage clips.
4. Move the wet mount using the **stage control knobs** so that the specimen appears to be right below the objective lens.
5. Looking from the side, turn the **coarse adjustment knob** to move the objective lens to as close as possible to the stage or specimen.
6. Now looking through the eyepiece, bring the specimen into focus using the **coarse adjustment knob** and *perfect* the focus with the **fine adjustment knob**.
7. Once the specimen is in focus and further magnification is required, turn the objective lens to the next higher power and fine focus. This can be done for 10X and 40X objectives.

Note: Specimens to be observed under 100X objective lens requires oil of immersion (Cannot be done for wet mounts)

Calculating Total Magnification

Total Magnification: Eyepiece Lens $\times$ Objective Lens

Example: The total magnification when eyepiece lens is 10X and the objective lens is 40X is equal to

Total Magnification (TM): $10 \times 40 = 400X$

Calculating Diameter of Field of View (FOV)

If the diameter of the FOV is not known:

1. Put the objective on low power.
2. Place a clear plastic ruler (mm) across the FOV.
3. Bring the ruler into focus.
4. Record the number of ruler divisions seen across the diameter at low power.
5. Using that diameter calculate the diameter of higher power.

Formula:

$$\frac{\text{TM at Low Power}}{\text{TM at High Power}} = \frac{\text{Diameter FOV at High Power}}{\text{Diameter FOV at Low Power}}$$

Rearranging the Formula:

$$\text{Diameter of FOV at Low Power} = \frac{\text{TM at High Power}}{\text{TM at Low Power}} \times \text{Diameter FOV at High Power}$$

OR

$$\text{Diameter of FOV at High Power} = \frac{\text{TM at Low Power}}{\text{TM at High Power}} \times \text{Diameter FOV at Low Power}$$

Example on Calculating Diameter of Field of View (FOV)

If the diameter of FOV at 4X Objective and 10X eyepiece is 4 mm then the diameter (mm) of FOV at 40X Objective will be:

$$\text{Diameter of FOV at High Power} = \frac{\text{TM at Low Power}}{\text{TM at High Power}} \times \text{Diameter FOV at Low Power}$$

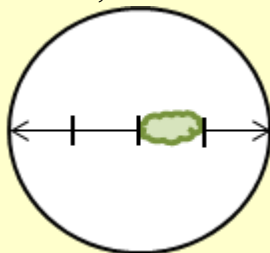
$$\text{Diameter of FOV at High Power} = \frac{40X}{400X} \times 4 \text{ mm}$$

$$\text{Diameter of FOV at High Power} = \mathbf{0.4 \text{ mm}}$$

Estimating Cell Size

$$\text{Cell Size (mm)} = \frac{\text{Diameter of FOV (mm)}}{\text{Estimated \# of times the specimen fits across}}$$

Example: The estimated cell size in micrometres (μm) viewed at High Power (40X Objective and 10X Eyepiece) if the diameter of FOV at Low Power (4X Objective and 10X Eyepiece) is 4 mm, would be:



Step 1: Calculate the Diameter of FOV at High Power

$$\text{Diameter of FOV at High Power} = \frac{\text{TM at Low Power}}{\text{TM at High Power}} \times \text{Diameter FOV at Low Power}$$

$$\text{Diameter of FOV at High Power: } \frac{40X}{400X} \times 4 \text{ mm} = \mathbf{0.4 \text{ mm}}$$

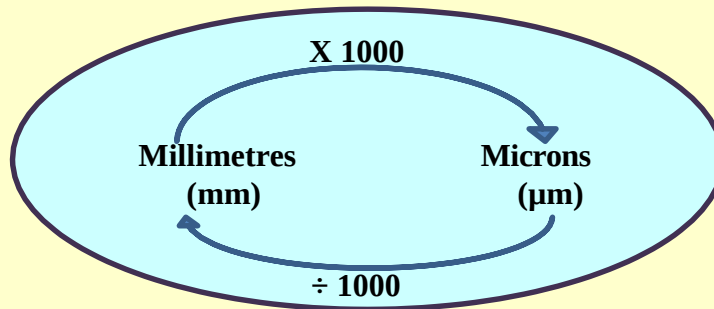
Step 2: Estimate the cell size using the formula

$$\text{Cell Size (mm)} = \frac{\text{Diameter of FOV (mm)}}{\text{Estimated \# of times the specimen fits across}}$$

$$\text{Cell Size (mm)} = \frac{0.4 \text{ mm}}{4} = \mathbf{0.1 \text{ mm}}$$

Estimating Cell Size Continued

Step 3: Convert millimetres (mm) to micrometres (µm)



$$\begin{aligned}\text{Size of the specimen in } (\mu\text{m}) &= 0.1 \text{ mm} \times 1000 \\ &= 100 \mu\text{m}\end{aligned}$$

Immersion Oil

- **Immersion oil** (also known as: oil of immersion) is used when focussing the specimen at 100X objective lens.
- **Why?**
Immersion oil reduces the refraction effect between the lens and the slide thus providing a crisp image.
- **Which Specimen?**
100X objective lens is used to magnify and resolve very tiny specimen. Example: bacteria and fungi spores.
- **How?**
To observe under 100X objective, wet mounts are not prepared; instead stained dry slides of the specimen is prepared and observed without a cover-slip. The slide is focussed at the lowest power objective (usually 4X), followed by fine focus on the next higher powers (10X and 40X), and finally at 100X objective lens. Just before turning onto 100X, a drop of immersion oil is placed on the slide.

Caring for a Microscope

Microscopes are expensive tools used by biologist frequently. Therefore its proper handling; care and storage are a must.

Handling Microscopes

1. When carrying a microscope from one place to another, always use one hand of yours to hold the microscope at its arm and place your second hand at the base of the microscope to provide support.
2. Never place a microscope near the very edge of the table where the chances of it falling down accidentally are high. Always place the microscope on a well-supported surface away from the edge.
3. If your microscope has wires for light source, place the wires securely on the table; never let it hanging, to avoid tripping and falling over.
4. Never wipe the lenses of the microscope with any ordinary tissue. This will spoil the lenses. There are specific tissues available to wipe the lenses.
5. Never look through the eyepiece while using coarse adjustment to focus. It can cause the stage to crash the objective lens.

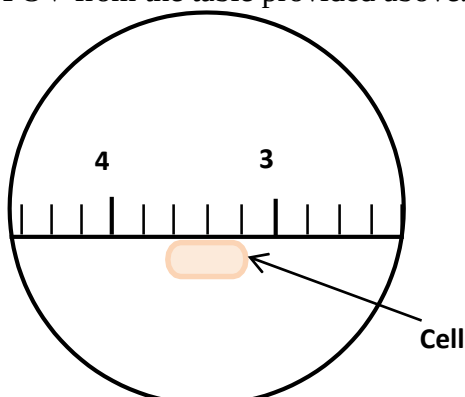
Storing Microscopes

1. After you have finished making your observation with the microscope; always bring the stage down and remove the slide. (Do Not Store the Microscope with the Slide)
2. Wipe the lenses with the special lens tissue and put the lowest power objective in place.
3. Turn off the light sources and wind up the wires securely.
4. Safely carry it back to the cupboard used for storing.



SELF TEST

1. Calculate the total magnification if the eyepiece lens is 5X and the lowest power objective lens is 4X.
2. Estimate the size of the cell (mm) observed at a total magnification of 400X. Use the diameter of FOV from the table provided above.



3. Convert the cell size calculated in Question (2) from millimetres to microns.
4. Calculate the diameter of FOV at 1000X magnification if the diameter of FOV at 40X magnification is 5 mm.
5. Suppose 8 cells fit across the diameter of FOV calculated in Question (4). What would the size of each cell be?

BI 12.1.1.2 CELL ORGANIZATION AND EMBRYONIC DEVELOPMENT

CELL ORGANIZATION

- ❖ Based on the Cell Nucleus, there are two types of cells: the **Prokaryote Cells** and **Eukaryote Cells**.

Prokaryotes

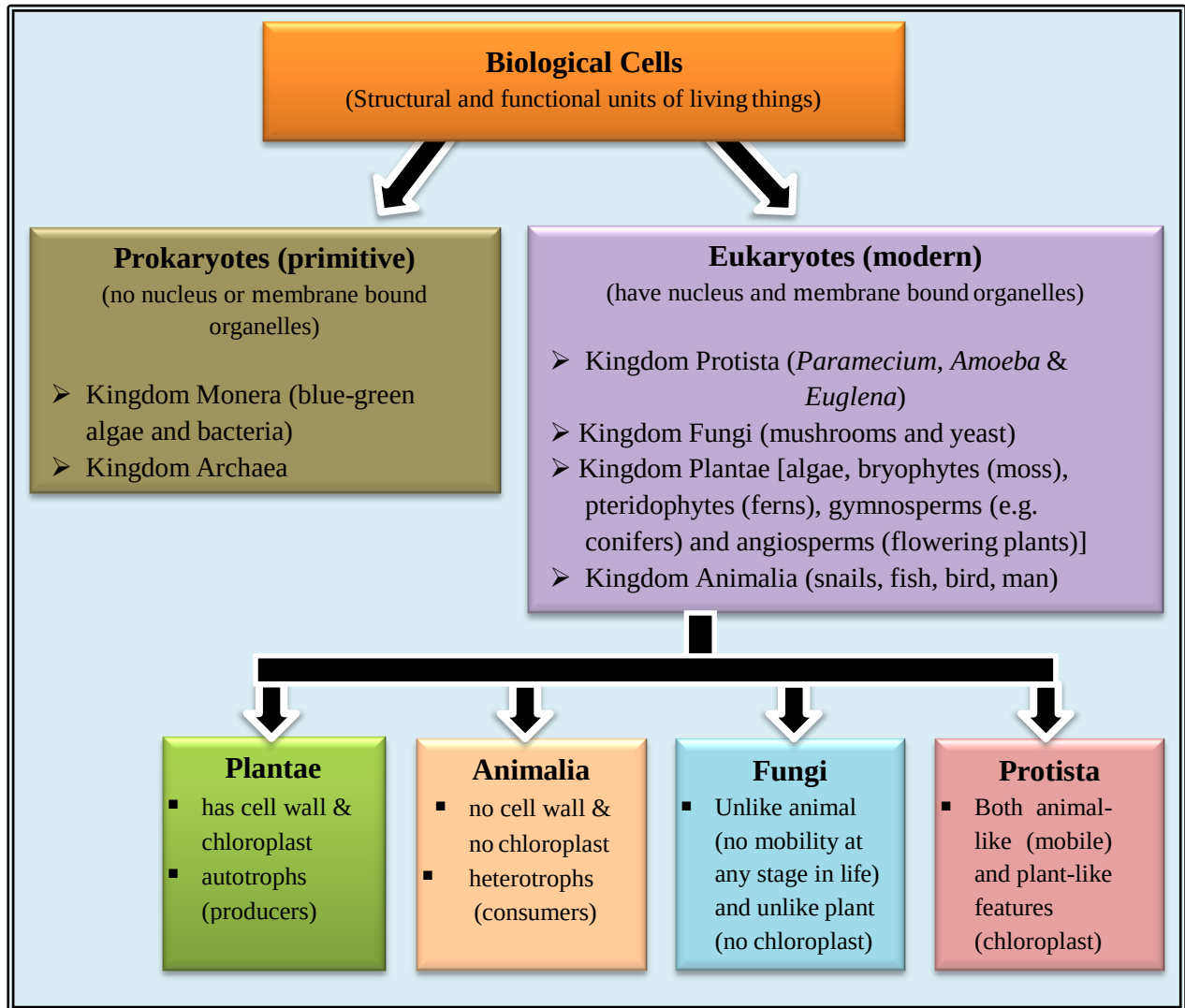
- ❖ The word **Prokaryotes** is derived from the ancient Greek where '*pro*' = 'before' and '*karyon*' = 'nut or kernel'.
- ❖ These organisms lack an organised cell nucleus or any other membrane-bound cell organelles. Most are unicellular, but some prokaryotes are multicellular.
- ❖ Example: Archaea (microorganisms living in cold deserts, hot springs, sulphuric marsh etc), Bacteria (microorganisms living in normal conditions) and Cyanobacteria (previously known as blue green algae).

Eukaryotes

- ❖ The word **Eukaryotes** is also derived from the ancient Greek where '*eu*' = 'good/true' and '*karyon*' = 'nut or kernel' referring to nucleus.
- ❖ These organisms have membrane bound nucleus and organelles.
- ❖ Example: Plants, Animals, Fungi and Protists.

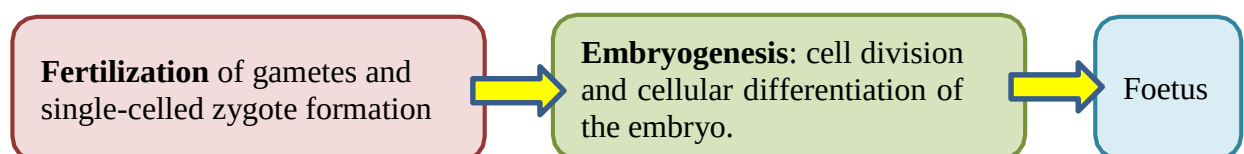
The major differences between both are:

Prokaryotes	Eukaryotes
❖ Cell wall made of muramic acid ❖ Chlorophyll contained in the chromatophores. ❖ No nucleus ❖ DNA lies in the cytoplasm ❖ Single circular chromosome + plasmid ❖ Endoplasmic reticulum absent ❖ Mitochondria absent ❖ Golgi Apparatus absent ❖ DNA replication in cytoplasm ❖ DNA replication unidirectional ❖ Transcription and translation occur simultaneously.	❖ Cell wall made of cellulose ❖ Chlorophyll contained in the chloroplast. ❖ Have membrane-bound nucleus ❖ DNA found in nucleus ❖ Many linear chromosomes ❖ Endoplasmic reticulum present ❖ Mitochondria present ❖ Golgi Apparatus present ❖ DNA replication in nucleus ❖ DNA replication bidirectional ❖ Transcription and translation occur in a sequence.



EMBRYONIC DEVELOPMENT

- ❖ Embryonic Development is the series of changes an embryo undergoes as it becomes a foetus.
- ❖ Development of an embryo is known as **embryogenesis**.
- ❖ Zygote is the first stage of life and starts after the fusion of egg and sperm (male and female gamete).
- ❖ When the first division in the fused cell (zygote) occurs, it no longer remains the zygote, it becomes an embryo. This is when embryogenesis occurs.
- ❖ In humans, at the later stage of pregnancy (after 8 weeks), the embryo stage ends and the foetus stage begins. The organs form in embryonic stage while the skeleton system in foetal stage.
- ❖ For this Year, we will only concentrate on the processes involved in embryogenesis.

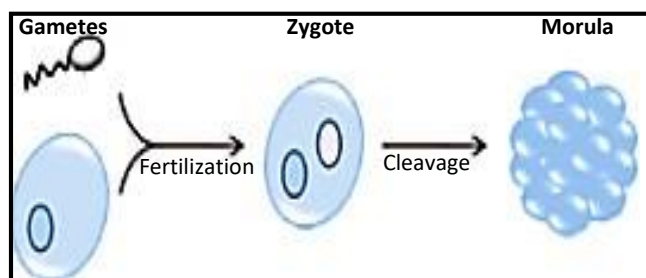


Process in Embryogenesis

1. Cleavage
2. Blastulation
3. Gastrulation

Cleavage

- ❖ Mitotic cell division of the zygote.
- ❖ Embryonic stage consisting of a solid, compact mass of 16 or more cells is known as **morula**.

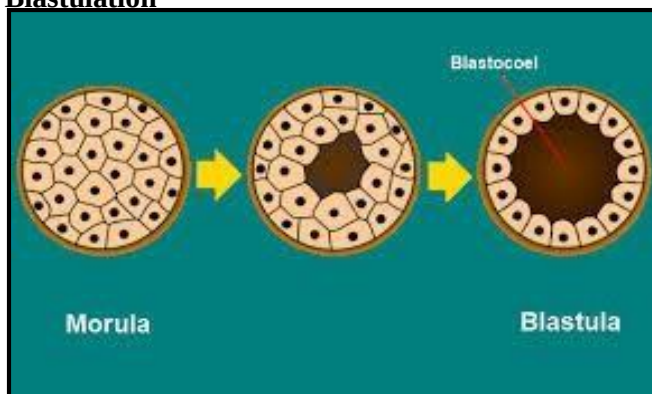


Source: www.epigenie.com

Blastulation

- ❖ Blastulation is the process via which the **morula** changes into **blastula**.
- ❖ Blastula is a hollow sphere of cells (also referred to as blastomeres) surrounding an inner fluid-filled cavity called the blastocoel.

Blastulation

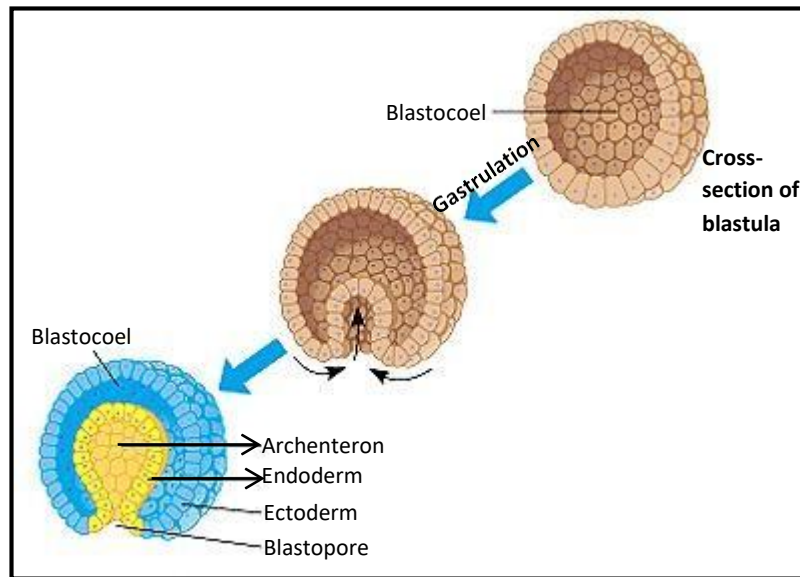


Source: www.web-books.com

Gastrulation

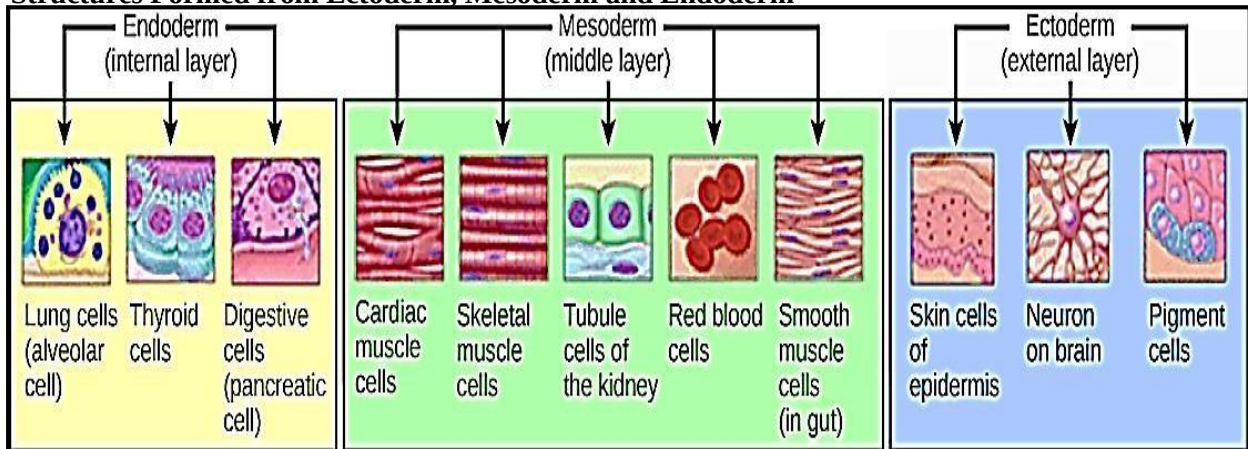
- ❖ Stage in which cell movements result in a massive reorganization of the blastula into three layered structure known as the **gastrula**.
- ❖ The differentiation of the gastrula into the three germ layers results in ectoderm, mesoderm, and endoderm.
- ❖ Gastrulation involves changes in cell motility, cell shape, and cell adhesion.
- ❖ Gastrulation creates a **blastopore** which is the opening to the archenteron.
- ❖ Archenteron is the invagination (turned inside out or folded back) of mesoderm and endoderm cells that will later become the digestive tract.

- ❖ The mesoderm forms via differentiation of the endodermal cells that cover the dorsal region of the archenteron.
- ❖ At **neurula** stage in embryogenesis, the ectoderm differentiates into neural tissues (nervous tissues).



Source: www.bio.miami.edu

Structures Formed from Ectoderm, Mesoderm and Endoderm



Source: <https://en.wikipedia.org>

Difference between Cleavage and Mitosis

- ❖ Cleavage divides the hollow ball into many cells; there is no cell growth. In mitosis, cell division is accompanied with cell growth.



SELF TEST

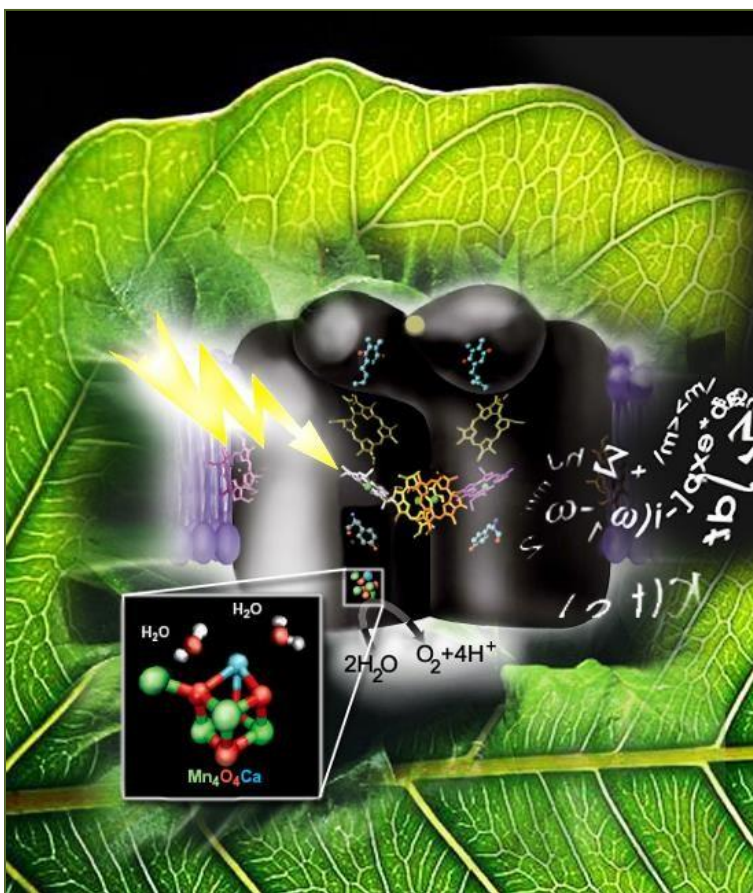
1. One of the most visible differences between prokaryotic and eukaryotic cells is the
 - A. presence of a cell wall in prokaryotes
 - B. presence of a nucleus in eukaryotes
 - C. lack of chlorophyll in eukaryotes
 - D. larger size of prokaryotes
2. Which type of cell appeared first on the earth?
 - A. Eukaryote
 - B. Prokaryote
3. DNA replication in prokaryotic cells occur in the cytoplasm because
 - A. it is unicellular.
 - B. it is a very primitive cell.
 - C. it has no endoplasmic reticulum.
 - D. it does not have a membrane bound nucleus.
4. What are the four initial stages of embryonic development?
5. What is cell division during the first stage of embryonic development called? How can this stage be described?
6. After the morula stage, what is the next stage? What is the morphological feature that defines this stage?
7. What are the archenteron and the blastopore? During what stage of embryonic development are these structures formed? What happens to the archenteron?
8. What is the difference between cleavage and gastrulation? Which occurs first?
9. From which germ layer is the epidermis and the nervous system produced? What other organs and tissues are made from that germ layer?
10. From which germ layer are blood cells produced? What other organs and tissues are made from that germ layer?
11. From which germ layer is the liver and the pancreas produced? What other organs and tissues are made from that germ layer?
12. What is the major distinguishing factor that separates the embryonic stage from the foetal stage?
 - A) All major organ systems form during the embryonic stage; the foetal stage consists mainly of rapid growth.
 - B) The brain forms late in the foetal stage; all other organ systems form earlier.
 - C) The skeletal system is laid down during the foetal stage, otherwise organ systems form during the embryonic stage.
 - D) The major event of the embryonic stage is implantation in the uterus; all development occurs during the foetal stage
13. In which process do the cells become progressively smaller?
 - A) Differentiation
 - B) Cleavage
 - C) Growth
 - D) Morphogenesis
14. Identify three types of changes the cells experience in gastrulation.

STRAND 1

YEAR 12

SUB-STRAND 1.2

METABOLIC CELL PROCESSES



SUB-STRAND 1.2: METABOLIC CELL PROCESSES

ACHIEVEMENT INDICATORS

At the end of this sub-strand, students should be able to:

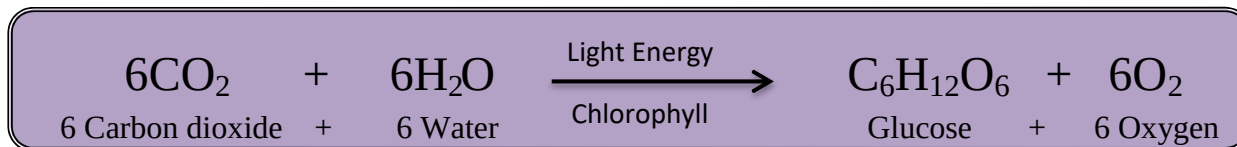
- ✓ Explain the types of energy transformation involved in the process of photosynthesis and respiration.
- ✓ Describe the roles of the essential components of photosynthesis and respiration.
- ✓ Describe the detailed structure of the chloroplast and relate features to adaptations for photosynthesis.
- ✓ Differentiate and summarize the processes involved between the light phase and dark phase of photosynthesis.
- ✓ Conduct experiments to investigate the factors affecting the rate of photosynthesis.
- ✓ Analyse the experimental results by drawing graphs to explain how factors control rate of photosynthesis.
- ✓ Describe the detailed structure of mitochondria and relate features to adaptations for respiration.
- ✓ Differentiate and summarize the stages involved in respiration.
- ✓ Assess the experimental results by drawing graphs to explain how factors control rate of respiration.
- ✓ Describe the relationship between photosynthesis and respiration.
- ✓ Name and describe the elements and components that constitute the bio-chemicals of life.
- ✓ Describe the roles of the four bio-chemicals.
- ✓ Study the chemical reactions to formation of monomers and polymers.
- ✓ Analyse carbohydrates for their energy content (or food storage).
- ✓ Study the process of DNA replication and how the process results in the transmission and conservation of the genetic code.
- ✓ Explain the process of protein synthesis.

BI 12.1.2.1

PHOTOSYNTHESIS

Photosynthesis is the process that transforms light energy from the sun into chemical energy that is later used by organisms as an energy source to fuel their activities.

The equation that best describes this transformation process is:

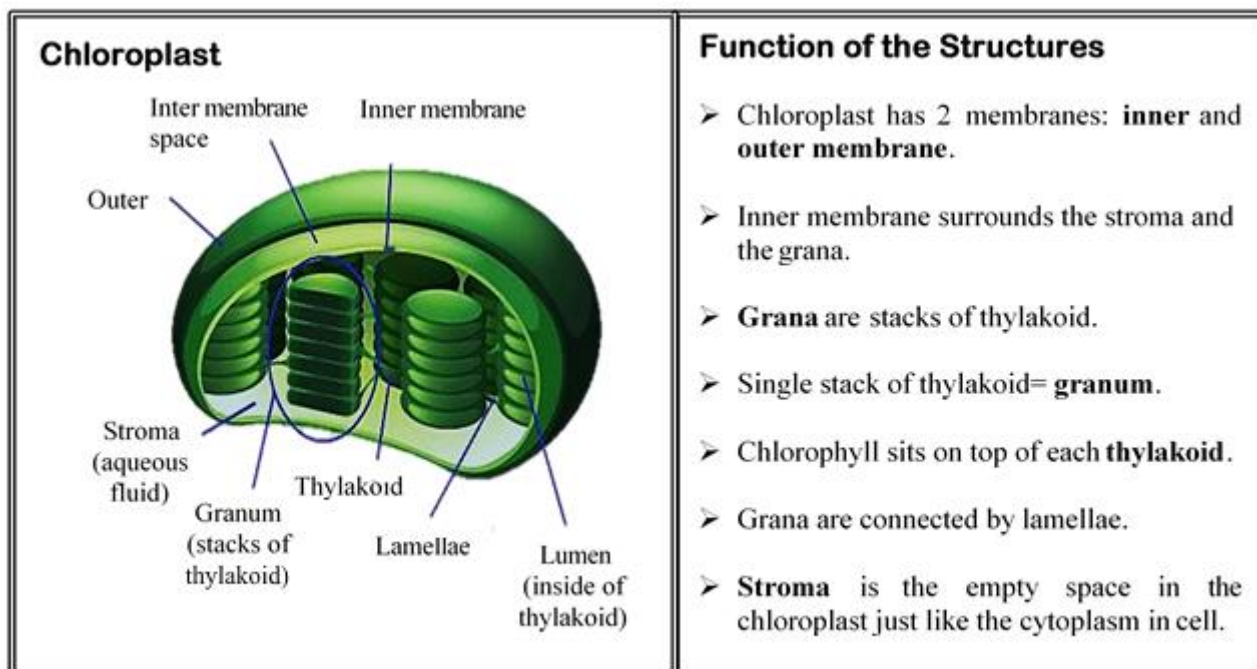


Key Ingredients for Photosynthesis

- ❖ **Carbon dioxide** – diffuses through the leaf stomata. The air spaces in the leaf allows CO₂ to diffuse to the palisade (cells containing chloroplast) cells quickly.
- ❖ **Water** – water is absorbed into the roots by osmosis and then transported to the rest of the plant.
- ❖ **Sunlight** - pigments (coloured proteins) found in the chloroplast traps sun's energy. The common pigments found in plants are:
 - Chlorophyll a and b: green pigment produced in chloroplast. These are photosynthetic pigments which absorb energy from the entire light spectrum except for green light.
 - Phaeophytin: yellow-grey pigment.
 - Xanthophyll: yellow-brown pigment.
 - Anthocyanin: red-pink pigment which mainly absorbs blue-green wavelengths.
 - Carotene: yellow-orange pigment. This pigment mainly absorbs the blue wavelength.

Site of Photosynthesis

The cell organelle responsible for carrying out photosynthesis is **chloroplast**. Structure of the chloroplast provided below will help you to better understand how the process of photosynthesis occurs.



Source: <http://www.biology.tutorvista.com>

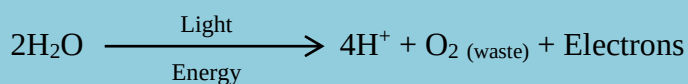
Stages of Photosynthesis

There are two stages of photosynthesis:

1. Light reaction (thylakoid membrane)
2. Dark reaction: Krebs cycle (stroma and cell cytoplasm)

Stage 1: Light Reaction: (light-dependent reaction)

Step 1: **Photolysis** - the light energy trapped by the pigments is used to split the water molecules. Oxygen is the by-product of this reaction. It diffuses out of the chloroplasts.



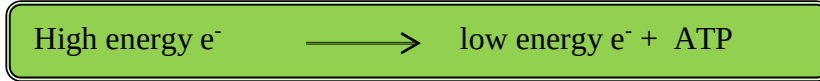
Step 2: **Exciting the electrons**- sunlight energises electrons released from water.

Step 3: **Electron transport chain**- high energy electrons released from splitting of water, moves back and forth across the thylakoid membrane to release their energy to into ATP. ATP is a high-energy molecule that is responsible for intracellular (inside the cell) energy transfer.

After the energy has been extracted from excited electrons, hydrogen ions (H^+) and electrons (e^-) are carried by NADPH and energy by ATP to the cell cytoplasm for the dark reaction. NADPH is like an 'electron taxi' responsible for dark reaction. NADPH is produced last in the light reaction.



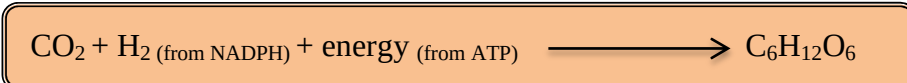
Source: www.clipartlord.com



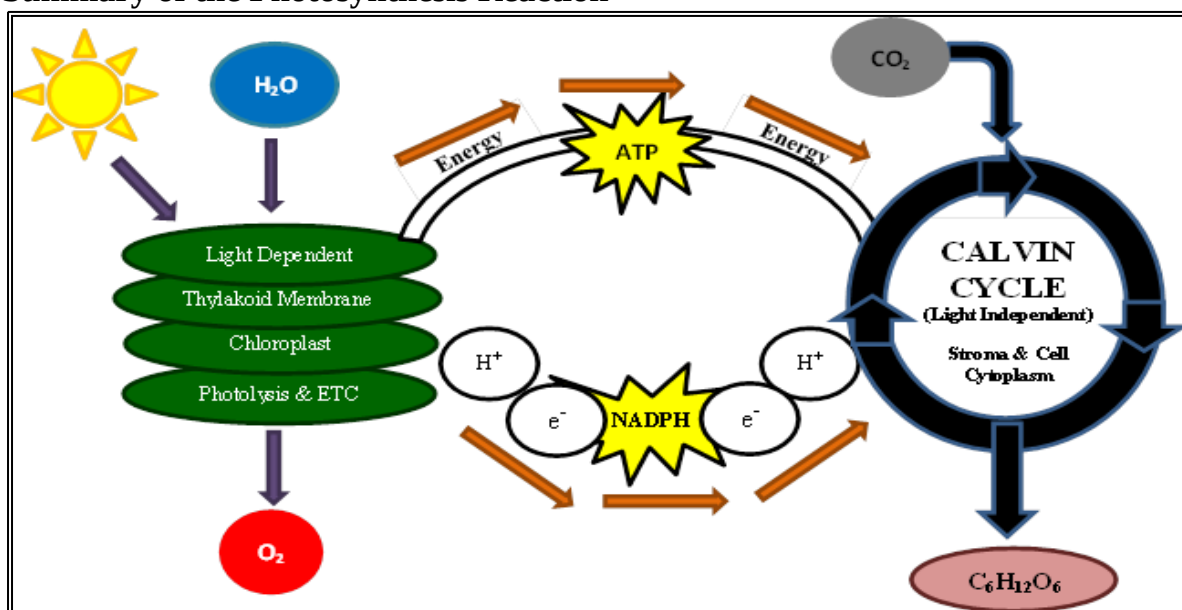
- ❖ **Photophosphorylation** is a process that uses light energy to add phosphate to ADP in order to produce ATP.
- ❖ Prokaryotes (e.g. cyanobacteria previously known as blue-green algae and some other bacteria) have simple systems in which photosynthesis is used just for the production of energy. Therefore, **cyclic photophosphorylation** occurs to accomplish the conversion of ADP to ATP process for immediate energy for the cells.
- ❖ In eukaryotes (plants) **non-cyclic photophosphorylation** occurs. This is accomplished by splitting the water molecule, converting ADP to ATP, and the provision of the reduced coenzyme NADPH to power the synthesis of energy storage molecules.

Stage 2: Dark Reaction: (light-independent reaction)

- H^+ and ATP from light reaction and CO_2 from the air react to produce glucose.
- Begins in stroma and finishes in the cell cytoplasm.
- Glucose is produced via complex cycle known as **Calvin cycle**.



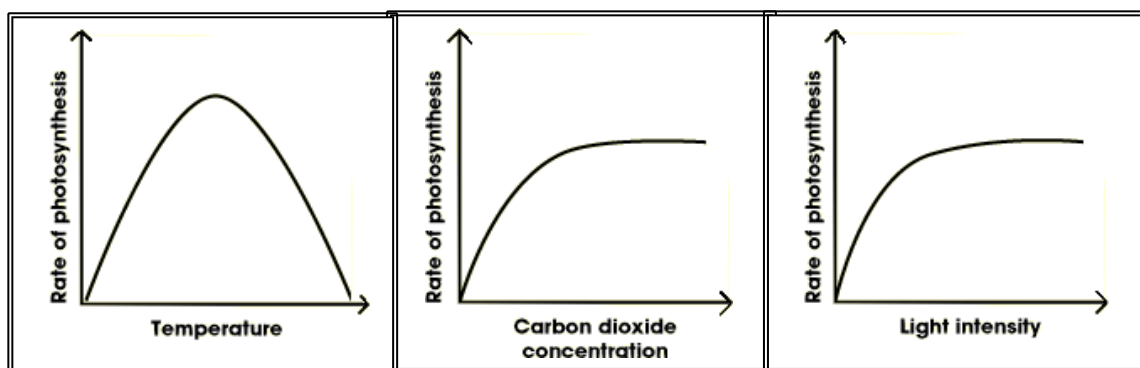
Summary of the Photosynthesis Reaction



Factors Affecting the Rate of Photosynthesis

Factors which influence the rate of photosynthesis are:

- 1) **Light Intensity** – is the strength or brightness of light. As light intensity increases the rate of photosynthesis increases provided sufficient water and carbon dioxide is present. However, this increase will be seen only till a certain increase in the light intensity. Beyond that increase, chlorophyll can get damaged.
- 2) **Carbon dioxide (CO₂) Concentration** – Increase in the carbon dioxide concentration will also increase photosynthesis since carbon gets incorporated as carbohydrate (C₆H₁₂O₆).
- 3) **Temperature** – it is not the light reaction that is affected by the change in temperature but rather the dark reaction. Temperature affects the enzymes which catalyses the reactions. All enzymes have optimal temperatures at which they work best and anything below or beyond affect their ability to catalyse reactions.



- 4) **Water Availability** – when all other factors are present in sufficient amount, the amount of water available to the plants can also affect the rate of photosynthesis. There is no problem when enough water is present but the problem arises when there is water shortage. During water shortage, the stomata will remain closed to prevent transpiration hence the plant will be deprived of CO₂ since CO₂ enters the leaf through stomata.
- 5) **Mineral & Nutrient Availability** - Among nutrients, low supply of nitrogen adversely affects the rate of photosynthesis since it forms the basic constituent of chlorophyll. Other essential elements which participate in photosynthesis (e.g. Mg, Fe, Cu, Mn, Cl, S and K) also affect the rate of photosynthesis.

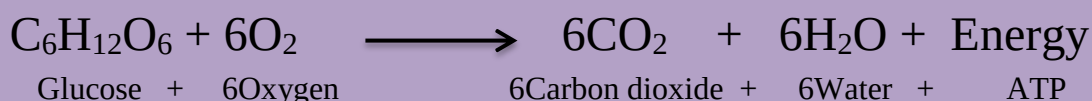
Respiration is the process that converts biochemical energy from food into ATP. Unlike photosynthesis which only occurs in plants and plant-like prokaryotes, respiration occurs in both the plants and animals. Plants photosynthesize during the day and respire at night.

Types of Respiration

- 1) **Aerobic Respiration:** breaks down glucose using oxygen. It extracts more ATP from food than anaerobic respiration.
 - 2) **Anaerobic Respiration:** breaks down glucose without oxygen. It extracts less ATP than aerobic respiration.
- ❖ Since aerobic respiration is more efficient, most organisms use anaerobic respiration only when no oxygen is available.

Aerobic Respiration

The equation that best describes the aerobic respiration is:

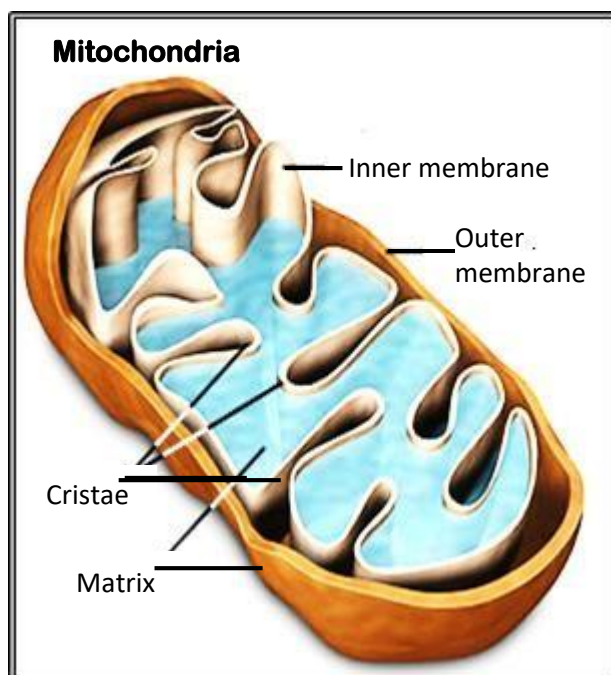


Key Ingredients for Aerobic Respiration

- ❖ **Carbohydrate** – organisms obtain carbohydrates from plants which produce carbohydrate/glucose via photosynthesis.
- ❖ **Oxygen** – is also produced by the photosynthesising organisms. It is a by-product of the light cycle in photosynthesis.

Site of Aerobic Respiration

The cell organelle responsible for carrying out cellular respiration is **mitochondria**. Structure of the mitochondria given below will help you to better understand how the process of respiration occurs.



Source: <http://www.micro.magnet.fsu.edu.com>

Function of the Structures

- Mitochondrion (singular noun) has 2 membranes: inner and outer membrane.
- Outer membrane covers the organelle.
- Inner membrane folds many times creating a layered structure called **cristae**. The folding of the inner membrane increases the surface area to volume ratio inside the organelle.
- **Matrix** is the fluid contained in the mitochondria.
- Mitochondria have its own ribosomes and DNA floating in the matrix (To be studied later).

Stages of Aerobic Respiration

Aerobic respiration occurs in three stages:

1. Glycolysis (cell cytoplasm)
2. Krebs Cycle (mitochondria matrix)
3. Respiratory Electron Transport Chain (cristae)

Stage 1: Glycolysis

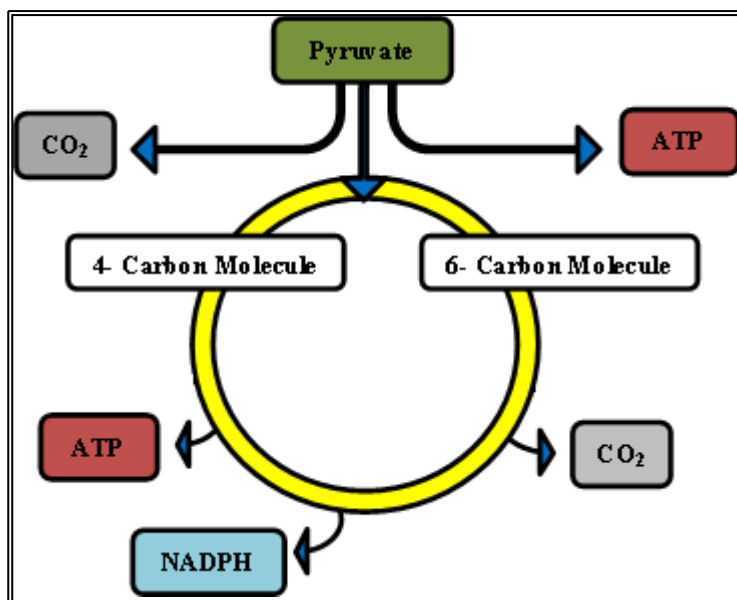
- ❖ Occurs in cell cytoplasm
- ❖ Splits glucose molecule into two pyruvate molecules
- ❖ Few molecules of ATP also produced
- ❖ No oxygen required



Stage 2: Krebs Cycle

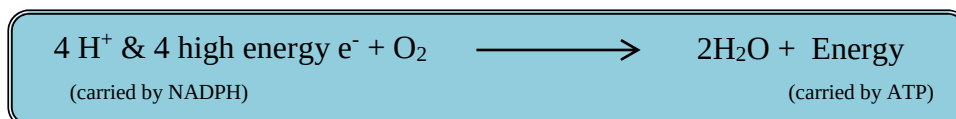
- ❖ Occurs in matrix.
- ❖ Breaks down pyruvate to produce more energy.

- ❖ Three products formed by breaking the pyruvate are:
 1. CO_2 (waste product)
 2. energy (carried by ATP)
 3. hydrogen ions (H^+) and electrons (e^-) (carried by NADPH)
- ❖ ATP produced is used by organism as a source of energy and CO_2 is excreted from the body. The hydrogen ions and electrons are carried to the last stage of the respiration- Electron Transport Chain.



Stage 3: Respiratory Electron Transport Chain (ETC)

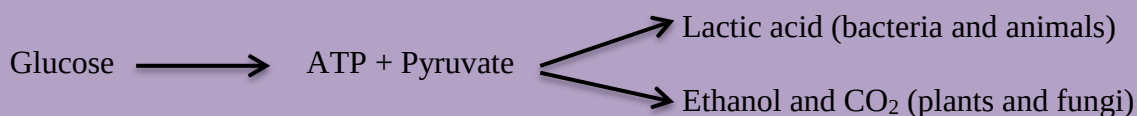
- ❖ Similar to the ETC in photosynthesis.
- ❖ Majority of the energy contained in the glucose molecule is released.
- ❖ High energy electrons from Krebs cycle move back and forth across the cristae until all its energy has been released into the ATP molecules.
- ❖ After all the energy is released from the electrons and hydrogen ions, oxygen is used to neutralise it by combining it to form water.



Anaerobic Respiration

- ❖ Small amounts of energy released from glucose.
- ❖ Oxygen not used.
- ❖ Disadvantages of anaerobic respiration is:
 1. Maximum amount of energy cannot be extracted from the glucose
 2. The by-product (lactic acid) can be poisonous to the cells if produced in large quantities.
- ❖ Advantage- some energy can be released in absence of oxygen.

The equation that best describes the anaerobic respiration is:



Stages of Anaerobic Respiration

- ❖ The only stage in the anaerobic respiration is: Glycolysis.
- ❖ In absence of oxygen, only glycolysis can occur to breakdown glucose into pyruvate and small amount of ATP.

Uses of Anaerobic Respiration

- ❖ Backup Energy supply for muscles- when carrying out vigorous exercise, our heart and lungs are not be able to supply sufficient oxygen to our muscles and in such cases muscles begin to carry out anaerobic respiration until more oxygen is available.
- ❖ Fermentation- fermentation by yeast is used in baking and brewing. Fermentation by bacteria is used in yogurt and cheese making processes.

Factors Affecting Respiration

Factors influencing the rate of respiration are:

- 1) **Glucose Availability** – glucose is the source of energy in respiration and in presence of sufficient glucose, cellular respiration will proceed effectively.
- 2) **Oxygen Concentration** – greatly influences the breakdown of glucose and the amount of energy in the form of ATP released. Aerobic respiration is only able to occur in presence of oxygen.
- 3) **Temperature** – activity of enzymes affected if the temperature is not in the optimal range.
- 4) **Cell Activity** – the rate of respiration is highly dependent on the cell activity. During vigorous activities such as exercising, the respiration rate increases and it decreases while the body the resting or sleeping.

Comparison between Photosynthesis and Respiration

Photosynthesis	Respiration
Occurs in plants and some prokaryotes (not in animals)	Occurs in plants, animals and prokaryotes
Energy from light is required	Energy acquired from chemical reaction
Producers	Producers and Consumers
Organism which photosynthesize are self-sustaining	Organisms highly rely on the producers to survive
Reactants are CO ₂ and water	Products are CO ₂ and water
Products are glucose and O ₂	Reactants are glucose and O ₂
By-product produced: O ₂	By-product produced: CO ₂
Occurs in chloroplast	Occurs in mitochondria
Electron transport chain	Electron transport chain



SELF TEST

- Which organisms contain chloroplasts?
- Where does the plant get energy to make its food?
- What is the process conducted by the producers?
- What are the raw materials (reactants) used for photosynthesis?
- Which simple sugar is produced in photosynthesis?
- Which gas is used and which is released in photosynthesis?
- Which part of the plant contains most of the photosynthetic cells?
- Where in the chloroplast (organelle) is chlorophyll (pigment) found?
- What is the role of stomata in photosynthesis?
- How many membranes are found in chloroplast and mitochondria?
What is the empty space (space similar to cytoplasm) known as in the chloroplast and in the mitochondria?
- What are stacks of thylakoid known as and how are these stacks connected?
- What happens in photophosphorylation?

13. In photosynthesis process where (light reaction or dark reaction) is CO_2 used?
14. What happens in photolysis?
15. What are ATP and NADPH?
16. What are some factors limiting the rate of photosynthesis?
17. What is the difference between respiration and gas exchange?
18. What is the difference between aerobic and anaerobic respiration?
19. What is the primary purpose of cellular respiration?
20. What is needed for cellular respiration to occur?
21. What are waste products in aerobic cellular respiration?
22. What are the waste products in anaerobic respiration in plants and animals?
23. How is the numerous folding of the inner membrane (cristae) of mitochondria advantageous?
24. What are some uses of anaerobic respiration?
25. Muscle cells require more energy than do most other cells. Which organelles would you expect to find in greater abundance in muscle cells than in most other cells?
26. How are photosynthesis and respiration opposite processes?
27. How are the by-products of respiration released from the body?
28. What are factors which limit cellular respiration?
29. Identify the similarities between the chloroplast and mitochondria.

The four organic (carbon containing) molecules that make up the living things are:

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic Acids

1. CARBOHYDRATES



Source: www.wholebodyhealthohio.com

Structure

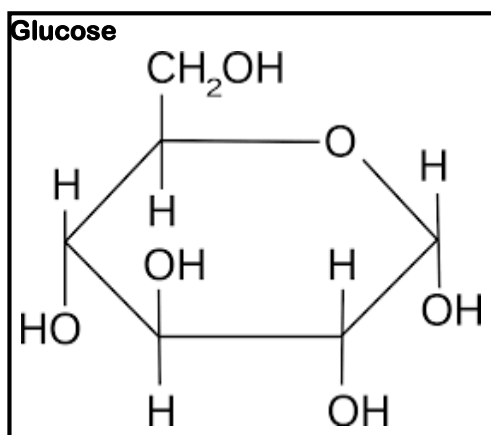
- ❖ Simple sugar molecules made of carbon, hydrogen and oxygen atoms.
- ❖ It can be linked into long chains to form complex carbohydrates.
- ❖ Simplest sugar ring is known as monosaccharide (mono - one; saccharide - sugar).
- ❖ Some carbohydrates can be made from joining two (disaccharide) or more (polysaccharide) sugar rings.

Functions

- ❖ Is used for structure and energy storage; quick source of energy.
- ❖ Making up the cell structure.

Examples of Carbohydrates

1. **Monosaccharides**- single sugar molecule. Example: Glucose, Fructose and Galactose.



Source: www.suppreviewers.com

2. **Disaccharides**- two sugar molecules joined together. Example: Lactose (milk), Sucrose (table sugar) and Maltose (molasses).
3. **Polysaccharides**- many simple sugar molecules joined together. Example:
 - i. **Glycogen**- made of many glucose molecules. Glycogen is the form in which animal/ human body stores glucose.
 - ii. **Starch**- large number of glucose joined together. It is produced by many green plants as a source of energy.
 - iii. **Cellulose**- made up of hundreds and even thousands of glucose units. It is an important component of the cell wall.
 - iv. **Chitin**- a polysaccharide found in the cell wall of fungi, exoskeleton of the arthropods and radula of the molluscs.

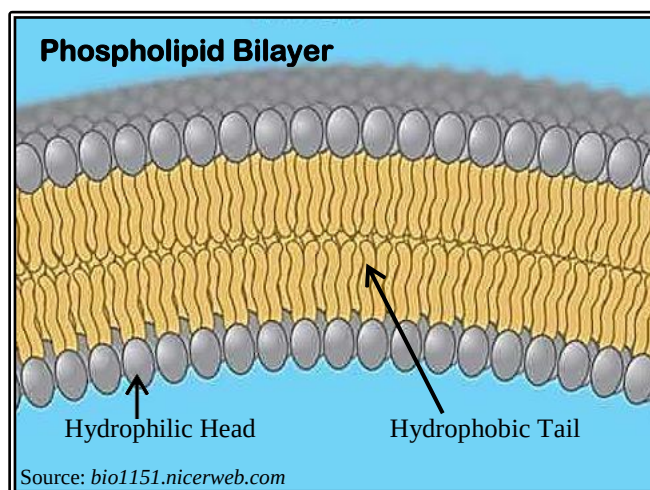
2. LIPIDS



Source: www.livestrong.com

Structure

- ❖ Made of carbon and hydrogen molecules.
- ❖ Do not dissolve in water.
- ❖ Fats and oils fall in this category. For example, ghee butter, oils, margarine, wax.
- ❖ Basic structure: **Long fatty acid tail** attached to **glycerol** molecule.
- ❖ Contains twice the amount of energy as the carbohydrates.



Source: bio1151.nicerweb.com

Functions

- ❖ Development of cell membrane - Phospholipid bilayer.
- ❖ Long-term energy storage.
- ❖ Insulation to keep the body warm.
- ❖ Provides padding and protection to the internal organs.
- ❖ Aids in the absorption of vitamins A, D, E and K.
- ❖ Component of the steroid hormones.

Type of Fats

Saturated Fat

- No double bonds between carbons
- Solid at room temperature
- Mostly animal fats
- Excess consumption contributes to NCDs
- Examples: butter

Unsaturated Fat

- Double bonds between carbons
- Liquid at room temperature
- Mostly vegetable fats
- Not unhealthy in moderate consumption
- Example: soya bean oil

3. PROTEINS

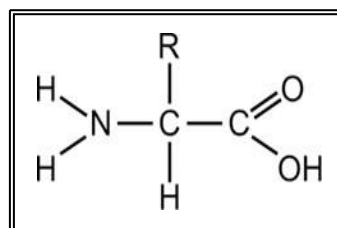


Structure

- ❖ Large molecules made of chains of amino acids.
- ❖ Contains carbon, oxygen, hydrogen and nitrogen atoms.
- ❖ There are **only** 20 amino acids but these twenty can be combined in several ways to produce approximately a million different proteins.
- ❖ Plays an important role in an organisms functioning.
- ❖ Some examples of proteins are: skin, hair, bones, cartilages, hormones, enzymes and muscle tissues.
- ❖ Four levels of protein structure are: Primary, Secondary, Tertiary and Quaternary structures. (only primary structure will be studied in Year 12).

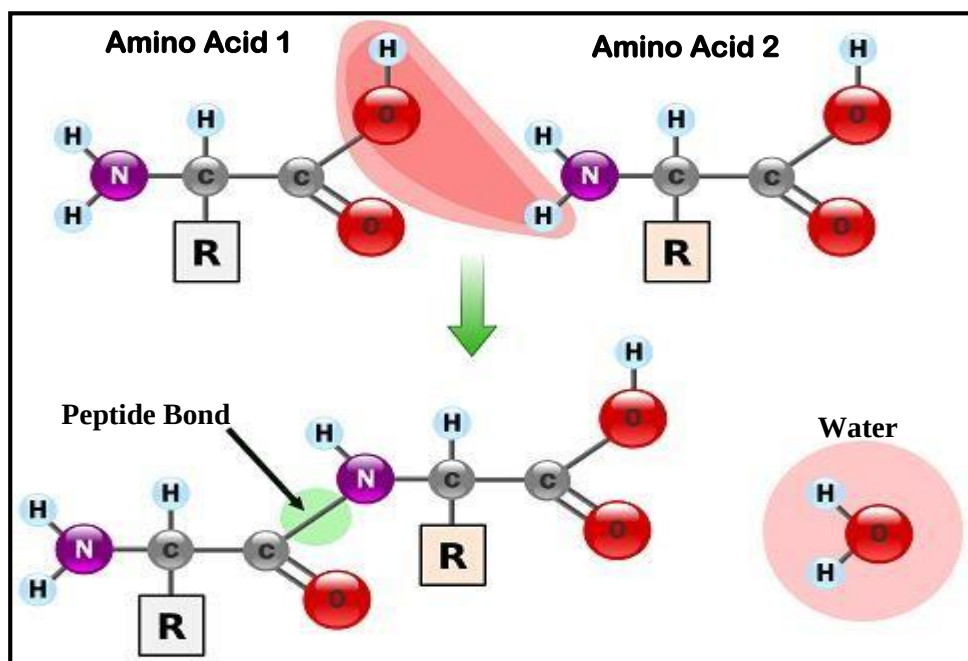
Basic amino acid structure

- Carbon centre
- COOH- carboxylic acid group
- NH₂- amino group
- R- varying attachment group



Protein Formation

- ❖ Nitrogen of one amino acid attached to the carbon of the carboxylic acid group of another.
- ❖ The two amino acids are joined by the **peptide bond**.
- ❖ More than two amino acids joined by peptide bond are known as **polypeptide chain**.



Source: [http:// www.study.com](http://www.study.com)

Functions

- ❖ **Antibodies**- proteins form antibodies, a component of the immune system that helps prevent infections and illnesses.
- ❖ **Energy**- protein is the major source of energy.
- ❖ **Enzymes**- enzymes are proteins which speed up chemical reactions in the body.
- ❖ **Hormones**- protein is involved in production of hormones such as insulin, secretin etc.
- ❖ **Transportation and storage of molecules**- major transportation element in the body. For example haemoglobin (protein) transports oxygen in the body. Ferritin is a protein that combines with iron and stores it in the liver.
- ❖ **Repair and maintenance**- protein is vital in development, maintenance and repair of the body tissues.

Denaturation

- ❖ Denaturation is the process whereby the shape of the protein is changed due to excess heat, corrosive chemicals, change in pH, change in the salinity levels and the concentration of heavy metals.
- ❖ The basic amino acid structure remains the same; only the shape of the protein is altered.
- ❖ Without the proper shape, proteins cannot function properly.
- ❖ Some proteins have the ability to 'un-denature' (go back to original shape) if placed back in the ideal conditions.

Body Building Proteins

- ❖ Proteins are broken into amino acids in our body.
- ❖ Proteins not required immediately by the body is deaminated (breaking of amino acid) by the liver.
- ❖ The amino group is converted to urea and filtered out of the blood in the kidneys which is then excreted.
- ❖ The remainder of the molecule is broken down for energy.

4. NUCLEIC ACIDS



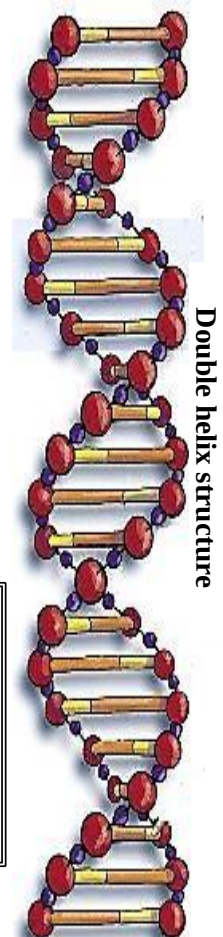
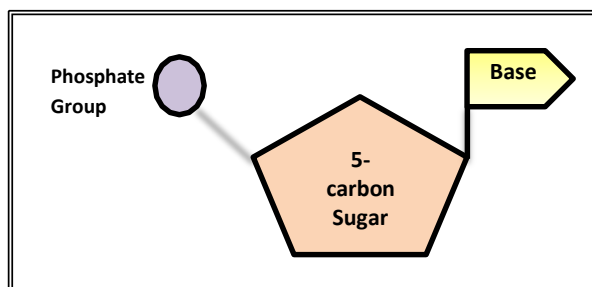
- ❖ While carbohydrates, lipids and proteins are energy sources (building materials), nucleic acids are the 'instructors' which tells the cells how to:
 - (1) Assemble the building materials together; and
 - (2) Store and release energy in cells.

Types of Nucleic Acids and Nucleotides

- ❖ 2 types of nucleic acids which serve as 'instructors' are:
 - DNA (Deoxyribonucleic acid)
 - RNA (ribonucleic acid)
- ❖ Nucleotides which have roles in energy transformation and transport:
 - ATP (energy carrier in photosynthesis and respiration reactions)
 - NAD^+ and NADP^+ (hydrogen and electron carriers)

Structure

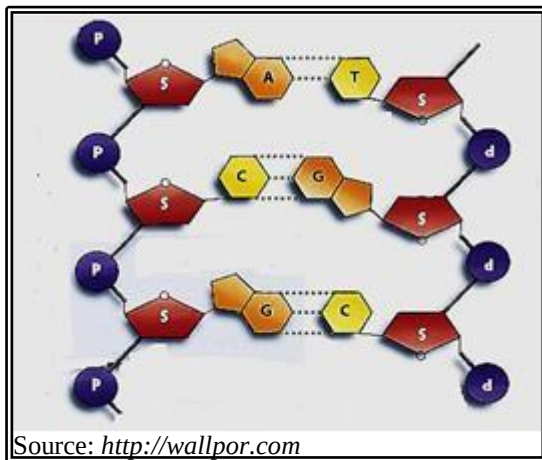
- ❖ Nucleotides are subunits which build the nucleic acids.
- ❖ Each nucleotide has 3 parts:
 1. Phosphate group
 2. 5-carbon sugar
 3. Organic base



Source: www.bio.miami.edu

Structure and Function of DNA

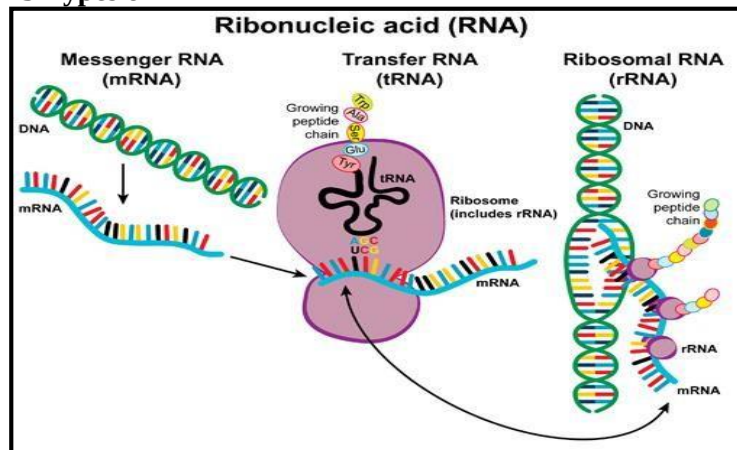
- ❖ DNA has a central role in regulating cell activity. It contains genetic information on which protein is to be made and how it should be made.
- ❖ DNA is **double stranded** (2 nucleic acids) twisted in a **spiral-helix** shape.
- ❖ DNA contains **four** different **nitrogen** bases:
 - Adenine (A)
 - Thymine (T)
 - Cytosine (C)
 - Guanine (G)
- ❖ Nitrogen base of one strand is joined to the nitrogen base of the other.
- ❖ Adenine pairs with thymine (A-T) and cytosine with guanine (C-G).



Structure and Function of RNA

- ❖ RNA is responsible for transcribing and translating the genetic information.
- ❖ When the cell needs to produce a certain protein, it activates the protein's **gene** (the portion of DNA that codes for that protein) and produces multiple copies of that piece of DNA in the form of messenger RNA (mRNA).
- ❖ The multiple copies of mRNA are then used to translate the genetic code into protein through the action of the cell's protein manufacturing machinery, the **ribosomes**.
- ❖ Instead of the nitrogen base Thymine (T), RNA's have the base 'Uracil' (U).
- ❖ There are three types of RNA:
 - (1) Messenger RNA (mRNA)
 - (2) Transfer RNA (tRNA)
 - (3) Ribosomal RNA (rRNA)

3 Types of RNA



Source: www.biology101.org

- ❖ RNA can also act as enzymes (called ribozymes) to speed chemical reactions.
- ❖ In some viruses, RNA, rather than DNA, carries the viral genetic information.
- ❖ It plays an important role in regulating cellular processes—from cell division, differentiation and growth to cell aging and death.

The major differences between DNA and RNA are:

DNA	RNA
❖ Double stranded	❖ Single stranded
❖ Has deoxyribose sugar	❖ Has ribose sugar
❖ Thymine (nitrogenous base)	❖ Uracil instead of Thymine

Summary Table of the Four Biochemicals				
	Carbohydrates	Lipids	Proteins	Nucleic Acids
Building block	monosaccharides	fatty acids + glycerol	amino acids	nucleotides
Elements	C H O	C H O	C H O N	C H O N P
Functions	- structure - quick energy source	- structure - long-term energy - storage - padding - insulation	- structure - hormones - enzymes - many other functions	- contain genetic information - carry energy, electrons and H⁺
Associated words	- mono: one - di: two - poly: more than two	- saturated - unsaturated	- peptide - peptide bond - denaturation	- DNA helix - A, T, C, G and U bases
Examples	- sugar - starch - glycogen - chitin	- phospholipids - butter - corn oil	- muscle fibres - insulin - egg white	- DNA - RNA - ATP - NADP⁺



SELF TEST

1. What should Manasa load-up in order to have abundant and quick energy for a rugby match?

A. Beef	B. Apples
C. Dalo	D. Vegetable soup

2. Apart from the thick fur, polar bears have a thick layer of fat (approximately 4.5 inches). Identify the reason for such a thick layer of fat?

A. Quick energy source	B. Make the fur grow thick and long
C. Provide heat insulation	D. No reason; they have the fat because they like to eat a lot.

3. If Sera wants to grow healthy and thick hair, which macromolecule should she increase in her diet?

A. Lipids	B. Proteins
C. Nucleic acids	D. Carbohydrates

4. If Frank converts a polymer into a monomer in his lab, how would the resulting product be?

A. No idea.	B. Larger than the starting material.
C. Same size as the starting material.	D. Smaller than the starting material.

5. A storage form of sugar found only in plants is

A. Chitin	B. Starch
C. Lactose	D. Glycogen

6. Keratin is a (Hint: mostly found in shampoos, conditioners, hair-gels etc.)

A. Lipid	B. Protein
C. Nucleic acid	D. Carbohydrate

7. Candle wax is insoluble in water. Therefore it must be a

A. Lipid	B. Protein
C. Nucleic acid	D. Carbohydrate

- | | PROTEIN | FUNCTION
(hormone; enzymes; energy; transport; storage; structure; defence; etc.) |
|----|----------------------|---|
| A. | Pepsin in stomach | |
| B. | Collagen and Elastin | |
| C. | Testosterone | |
| D. | Haemoglobin | |
| E. | Antibodies | |
| F. | Actin and myosin | |
| G. | Amylase | |

- ❖ A **catalyst** is any chemical that speeds up the rate of a reaction.
- ❖ Enzymes are organic (contains carbon atoms) catalysts.
- ❖ They are proteins that increase the rate of metabolic reactions.
- ❖ The names commonly end with 'ase'. Example: amylase, synthase, sucrose. However, the enzymes that were discovered very long time ago end with 'in'. Example: pepsin, trypsin
- ❖ For example, if you leave a spoonful of sugar undisturbed for thirty years, it will not change at all. However, if you eat the sugar, it will oxidise (broken down) in less than thirty minutes. This incredible difference in reaction rate is due to an enzyme.

Enzyme Reactions

1. Enzymes work by lowering a reaction's activation energy.

- ❖ Activation energy is the energy required to start up a reaction. For any reaction to occur the molecules involved must collide in the right way at high speed (this requires energy).
- ❖ Enzymes reduce the activation energy by binding to a substrate (grabbing) the molecules and holding them together in the right way until they react with each other. Once the reaction has finished, the enzyme breaks free.

2. Enzymes are not changed by the reaction they catalyse.

- ❖ A cell uses the same enzyme molecule over and over again. Chemical reactions do not affect the enzymes that catalyses them, that is, enzymes do not get used up by the reactants.

3. Each metabolic reaction has its own enzyme to catalyse it

- ❖ The chemicals that an enzyme acts on its called the substrate.
- ❖ Each enzyme acts on specific substrate.
- ❖ The substrate and its enzyme fit together like a lock and key.

4. Many factors affect the rate of enzyme action.

- ❖ Factors such as temperature, pH, substrate concentration, enzyme concentration and substrate surface area affects enzyme action.
- ❖ Every enzyme has temperature and pH conditions in which it works best. For example, stomach enzyme function best in acids. Most of your body enzymes work best at 37⁰C.
- ❖ Most chemical reactions which are enzyme catalysed generally proceed more quickly as temperature increases. However, this is true only up to a certain temperature because **enzymes are proteins** and proteins get denature if overheated.
- ❖ As substrate concentrations, enzyme concentrations and substrate surface areas increase, so does the reaction rate (as long as both substrate surface area and enzyme are available).

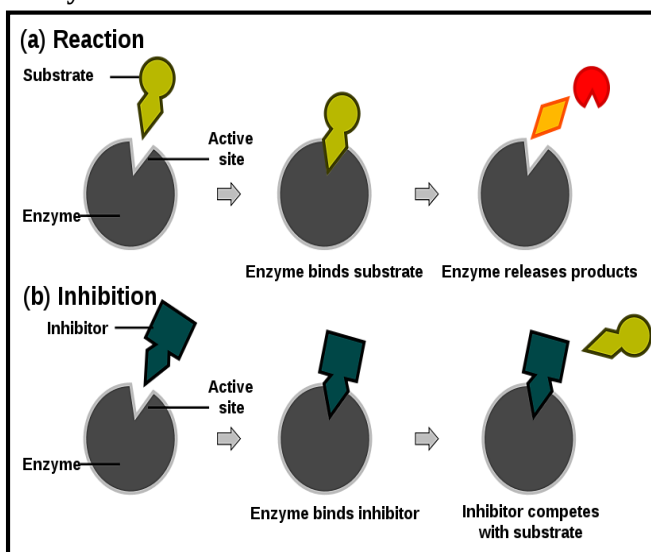
5. Inhibitors can prevent enzymes from acting on substrates

- ❖ Inhibitors are chemicals which prevents the enzyme from working until the organism need it. Every enzyme has an inhibitor made by the cell.
- ❖ By using inhibitors, a cell can control the effects of its enzymes.
- ❖ For example, when liver converts glycogen into glucose using enzyme (glycogen phosphorylase), then it does not want the enzyme which converts glucose into glycogen (glycogen synthase) to be working against it and therefore it produces an inhibitor to stop the enzyme (glycogen synthase) from converting glucose to glycogen.

6. Many enzymes require *co-factors* to function.

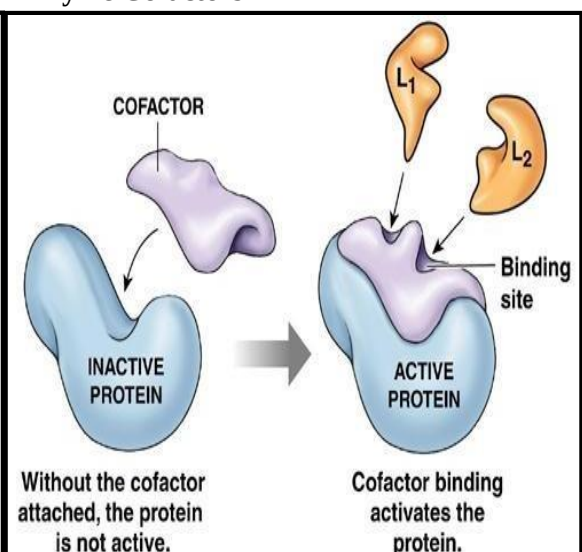
- ❖ Any substance that helps an enzyme to function is called a co-factor.
- ❖ Co-factors are usually vitamins or minerals.
- ❖ For example, vitamin B helps the enzymes that catalyses respiration. If a person does not get vitamin B in her diet, she will become paralysed. Eventually she will die because her cells cannot get energy out of food.

Enzyme Action



Source: www.en.wikibooks.org

Enzyme Cofactors



Source: www.studyblue.com

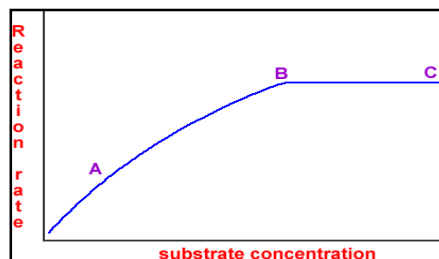


SELF TEST

1. Enzymes have the ability to catalyse reactions. How do the enzymes speed up reactions and what amount of it gets used up by the reaction?
2. Are all enzymes protein or all proteins enzymes?
3. Name some of the common enzymes that have important roles in human digestive system?

4. Based on the graph, which of the following could be used to increase the reaction rate beyond point C?

- A. Decrease enzyme concentration
- B. Increase inhibitors
- C. Decrease the temperature
- D. Increase the amount of substrate



5. The part of the enzyme where the substrate binds is called the:
- A. Active site
 - B. Large subunit
 - C. Inhibitor
 - D. Catalyst
6. When a piece of liver is dropped into hydrogen peroxide, the peroxide bubbles vigorously as a result of what reaction?
- A. peroxide being broken into water and oxygen
 - B. liver and peroxide are joining together to make a new protein
 - C. more peroxide is being created by the liver
 - D. peroxide is destroying germs in the liver
7. Some people cannot digest milk products because they lack a specific enzyme. Which enzyme would be used to break down the lactose in milk?
- A. hydroxylase
 - B. maltase
 - C. lactase
 - D. peroxisomes
8. Salivary amylase is a straight-digesting enzyme produce by your salivary glands. Some students spat 1ml of saliva into a test tube containing a little bit of starch and a drop of iodine solution.
- i. Identify the purpose of the iodine solution.
 - ii. After 20 minutes, the blue-black colour of the mixture disappeared. Why?
 - iii. The students repeated the same experiments, except this time they boiled the mixture after spitting into it. After 20 minutes, nothing had changed. The mixture was still a blue-black. The next day, there was still no change. Why?
9. Explain why we need inhibitors in our body.
10. What are co-factors?

The following reactions are some important biochemical reactions:

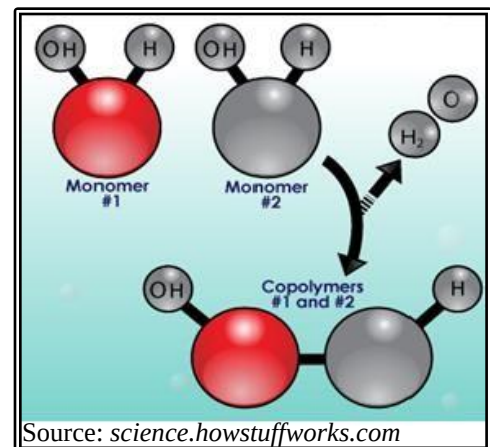
- (1) **Condensation Reaction**- building up the polysaccharides, lipids and polypeptide molecules.
- (2) **Hydrolysis Reaction**- breaking down polysaccharides, lipids and polypeptide molecules.
- (3) **DNA Replication**- DNA makes identical copies (replicas) of itself to pass on the daughter cells (new cells) before cell division.
- (4) **Protein Synthesis**- DNA encodes for the production of amino acids and proteins. The bases on DNA are transcribed and translated into proteins.
- (5) **Photosynthesis**- plants make food using carbon dioxide, water and sun's energy.
- (6) **Respiration**- cells release energy by oxidising the bonds in the food molecules.

Condensation and Hydrolysis Reaction

- ❖ Just like the photosynthesis and respiration reaction, condensation and hydrolysis are exactly opposite reactions. The reactant of one reaction is the product of the other.

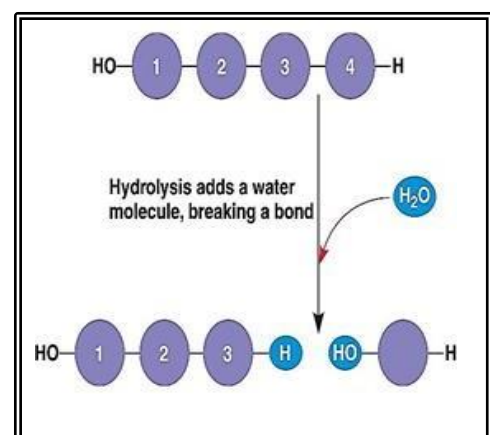
1. Condensation

- ❖ Link small biochemical building blocks to form larger molecules.
- ❖ Also known as '**dehydration**' reaction because water molecule is lost when joining two small molecules.
- ❖ For example, when two amino acids join to form a peptide, water is the by-product of the reaction.
- ❖ Starch produced by plants is via condensation reaction.



2. Hydrolysis (Hydro = water and Lysis = break)

- ❖ Breaking the large molecules into smaller biochemical building blocks.
- ❖ This reaction is a '**hydration**' reaction because it uses water.
- ❖ For example, during digestion:
 - starch is hydrolysed into glucose,
 - fats into fatty acids and glycerol,
 - proteins into amino acids.



3. DNA Replication

- ❖ DNA is a double strand of nucleic acids joined between the bases of the nucleotides.
- ❖ In order to pass the genetic information to the new cells (daughter cells), the old DNA strands make copies.
- ❖ The process of DNA replication is semi-**conservative** (semi = half; conservative = holding on) because the new DNA copy (replica) retains 50% of the information of the old/parent DNA.

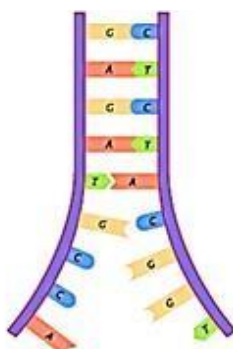
Steps in DNA Replication

- 1) The parent DNA helix unwinds and separates into two separate strands.
- 2) Nucleotides are attracted to the complementary bases.
- 3) Complementary base pairing occurs.
- 4) The new strands join together using enzyme (DNA polymerase).
- 5) There are two identical DNA helix, each consisting of the one original strand of DNA and one new strand.

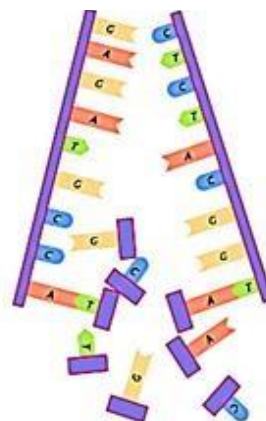
1. A portion of DNA which will undergo replication.



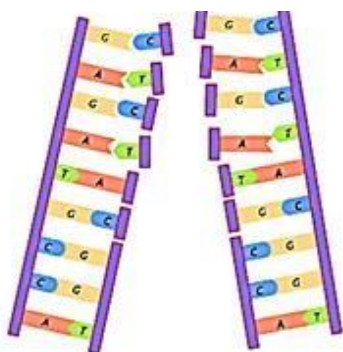
2. The 2 strands of DNA separate by breaking the hydrogen bonds between the bases.



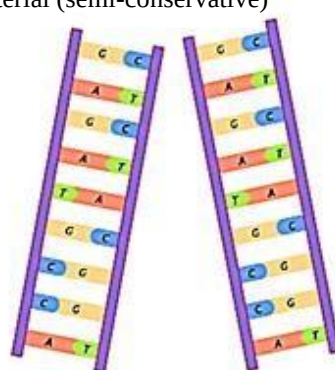
3. Free nucleotides attracted to their complementary bases.



4. The complementary base pairs are joined by the enzyme DNA polymerase.



5. All the nucleotides are joined by DNA polymerase. Two identical strands are formed. Each strand retains half of the original DNA material (semi-conservative)



Source: <https://y12hb.wordpress.com/2013/03/27/dna-replication-the-semi-conservative-method/>

4. Protein Synthesis

- ❖ Proteins are made inside cells.
- ❖ Protein synthesis is a process whereby DNA encodes for the production of amino acids and proteins.
- ❖ The instructions for how to make a protein are held inside the DNA molecule.
- ❖ The major stages in making a protein are: **DNA unwinding**, **transcription** and **translation**.

Steps of Protein Synthesis

i. DNA Unwinding

- DNA segment unwinds and separates
- Happens in the cell nucleus

ii. Transcription

- mRNA nucleotide matches the DNA base by base and complementary base-pairing occurs.
- In complementary base-pairing, Cytosine pairs with Uracil since RNA lacks thymine.
- Occurs inside the cell nucleus.
- The mRNA serves as messenger which carries the DNA code from the nucleus to the ribosomes on the endoplasmic reticulum. (moves from nucleus to cytoplasm)
- In the transcribed mRNA, a set of three bases form a code known as the **genetic code** for one of the twenty amino acids present.

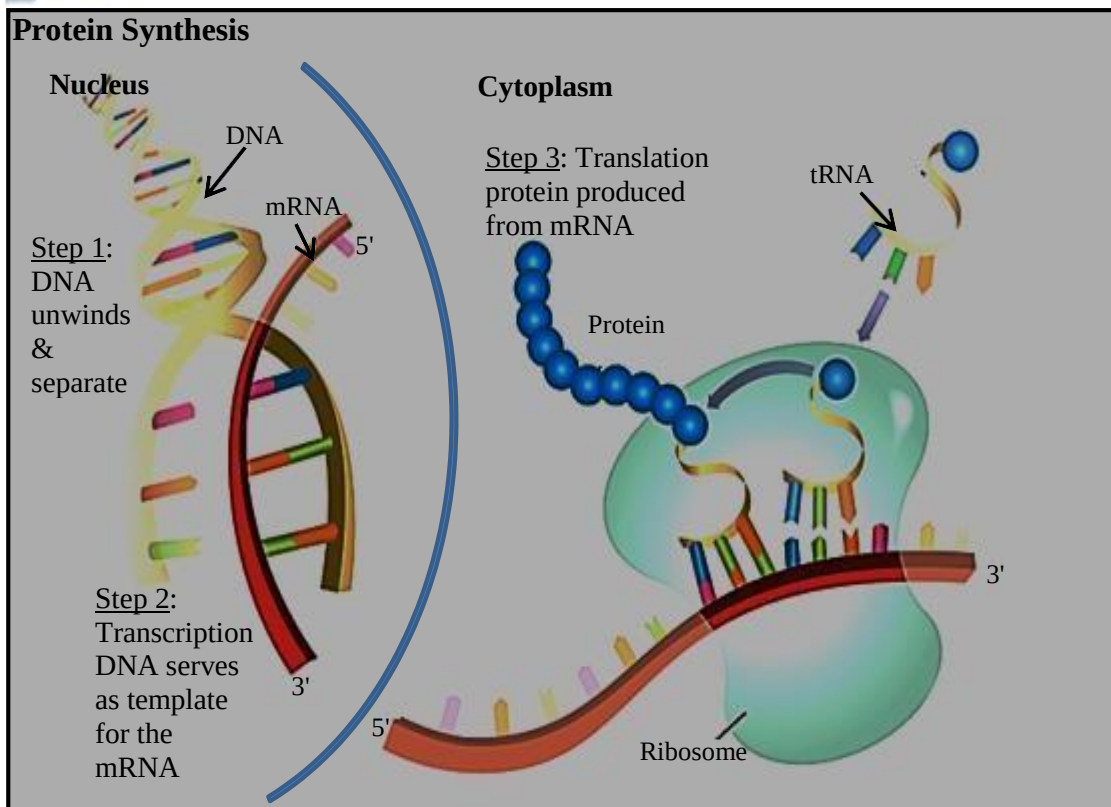
iii. Translation

- Occurs in the cytoplasm.
- tRNA brings amino acids matching the mRNA codons.
- Ribosomes move along the mRNA transcript.
- They form peptide bonds between amino acids and tell the t RNA where to place the next amino acid.
- Enzymes join several peptides together, creating a new protein.
- Golgi bodies make final adjustments to the protein and transport it in vesicles to the site where it is going to be used.
- The start codon begins the process; it is the first codon that gets translated.
- The **start codon** is AUG (Met/ methionine).
- When the ribosome reaches the **stop codon**, the translation finishes/stops.
- The three stop codons are UAA, UAG, UGA.

3 Main Steps in Translation

The ribosome moves along the mRNA codon by codon. It assembles the protein in the step below:

1. The ribosome calls RNA to bring the amino acid required by the mRNA codon.
2. The ribosome forms a peptide bond between the new amino acid and the one already in place.
3. The ribosome moves on to the next codon of the mRNA.



Source: www.ignyc.com



SELF TEST

1. Differentiate between the following processes:
 - i. DNA replication and protein synthesis
 - ii. Hydrolysis reaction and Condensation reaction

2. A set of codons read:
GCAUGUUAGCAUAUUGAC

Using the above mRNA strand:

- a. Identify the code that will initiate/start protein synthesis.
- b. Identify the code that will stop protein synthesis.
- c. Identify the proteins that are coded for by this genetic code.

		Second Letter							
		U		C		A		G	
1st letter	U	UUU Phe	UUC	UCU Ser	UCC	UAU Tyr	UAC	UGU Cys	UGC
		UUA	Leu	UUA		UAA Stop	UAG Stop	UGA Stop	UGG Trp
	C	CUU	Leu	CCU	Pro	CAU His	CAC	CGU Arg	CGC
		CUC		CCC		CAC	Gln	CGA	CGG
3rd letter	A	AUU	Ile	ACU	Thr	AAU Asn	AAU	AGU Ser	AGC
		AUA		ACA		AAA Lys	AAA	AGA Arg	AGG
	G	AUG Met		ACG		AAG		AGG	
		GUU	Val	GCU	Ala	GAU Asp	GAU	GGU Gly	GGC
		GUC		GCC		GAC	Glu	GGA	GGG
		GUA		GCA		GAA		GGA	
		GUG		GCG		GAG		GGA	

3. You are provided with the mRNA strand which reads: **AGCUCGAA**.
 - a. Write down the base order of the DNA from which this mRNA is transcribed.
 - b. For the DNA strand read achieved in part (a), identify the complementary bases found on the second strand of the helix.
4. Explain why DNA replication is a **semi-conservative** process.
5. Condensation of three monosaccharides are provided below:

Glucose + Glucose → Maltose + Water
 Glucose + Fructose → Sucrose + Water
 Glucose + Galactose → Lactose + Water

Write down the equations of the hydrolysis reaction of the disaccharides produced.
6. List down some of the hydrolysis and condensation reactions that serve important functions in the livelihood of the organisms (plant and animals).
7. State the function of each of the following nucleic acids and nucleotides.

a. DNA	d. ATP
b. mRNA	e. NAD ⁺
c. tRNA	f. NADP ⁺
8. Why does the DNA molecule need to replicate itself?
9. Lists some differences between DNA and RNA.
10. How is the DNA unwinding in protein synthesis different from DNA replication?
11. ‘Photo’ means light and ‘lysis’ means breaking. Given this, explain why ‘photolysis’ is an appropriate name for the first reaction in photosynthesis.
12. What happens to the oxygen produced in photolysis?
13. In three steps, explain what happens to the electrons produced in photolysis, including their final fate.
14. Draw a simple plant cell, including only a large chloroplast (with stroma and thylakoid membranes), the cell wall, and the nucleus. Label where each of the following reactions occurs:

a. Photolysis	b. electrons transport chain	c. Calvin cycle (dark reaction)
---------------	------------------------------	---------------------------------
15. Why is the second set of photosynthesis reactions called “dark” reactions?

16. List three things you could do to your pot plant to increase its rate of photosynthesis.
17. Do plants respire? Why or why not?
18. Which stage of aerobic respiration requires oxygen? For what is the oxygen used?
19. When do anaerobic respiration occur in humans? Name one advantage and one disadvantage of anaerobic respiration in humans?
20. Name two ways anaerobic respiration is economically important to us.

STRAND 1

YEAR 12

SUB-STRAND 1.3

GENETIC CONTINUITY



SUB-STRAND 1.3: GENETIC CONTINUITY

ACHIEVEMENT INDICATORS

At the end of this sub-strand, students should be able to:

- ✓ Explain using Mendelian genetics the concepts of dominance, co- dominance, recessiveness and gene linkage.
- ✓ Solve basic genetics problems and predict the outcome of various genetic crosses using Punnet method.
- ✓ Describe some processes that lead to variability.
- ✓ Explain genetic disorder in terms of the chromosomes affected.
- ✓ Discuss and compare the two theories of evolution.
- ✓ Describe the fundamental concepts related to evolution.
- ✓ Discuss and explain the processes that lead to speciation.
- ✓ Outline the evidences that support evolution.
- ✓ Define natural selection and its causes.
- ✓ Describe the features/mechanism of natural selection.

BI 12.1.3.1 GENETICS

REVISION OF IMPORTANT CONCEPTS

Genetics is the study of hereditary and variation. It involves inheritance (transfer) of physical and biological characteristics carried by **genes** and **alleles** from the parents to the offspring.

Terms:

- **Genes** are the units of genetic information (stretch of **DNA** on a chromosome) i.e. they provide instructions for making proteins.
- An **allele** is an alternate form of the gene coding for a particular trait (characteristic) such as blood type in animals or colour of flowers in plants.
- **DNA** is the chemical that genes and chromosomes are made of. DNA itself is made of nucleotides (chemical units) abbreviated as A, C, T and G, that can be read by cells during DNA replication.
- A **chromosome** is simply a very long piece of DNA that cells can easily copy.

Genotype and Phenotype

Genotype is the sum of all the genes an organism has. It is the inheritable information in the form of genetic codes that are used as the blueprint during cell division or reproduction, for building and maintaining living things.

Phenotype is the observable physical or biochemical characteristics of an organism which are influenced by both its genotype and by the environment. It is the outward appearance of an organism.

Example:

Genotype: the genetic code; (R) – tongue rolling (r) - non-rolle

Phenotype: ability or inability to roll tongue or not.



NB: The genotype codes for the phenotype.

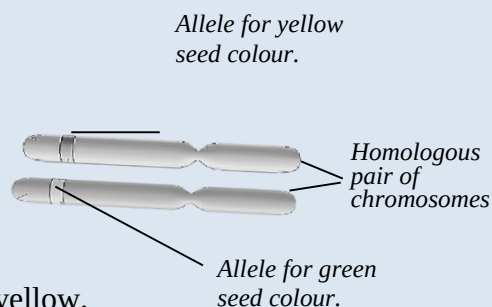
Dominant and Recessive

When an allele “covers up” the effect of another, it is the stronger or the **dominant** allele in an organism’s genotype. While the weaker, ‘**recessive**’ allele only affects the phenotype if both alleles of the pair are recessive.

A capital letter symbolizes a dominant allele while the small letter symbolizes the recessive allele.

Example: The gene for seed colour in pea plants exists in two forms. There is one form or allele for yellow seed colour (**Y**) and another for green seed colour (**y**). Here, the allele for yellow seed colour is dominant (stronger) while that for green colour is recessive (weaker).

Therefore, seeds with the genotype of (**YY**) or (**Yy**) are yellow, while seeds that are (**yy**) are green.



NB: When the alleles of a pair are different (heterozygous), the dominant (stronger) allele trait is expressed while the recessive allele trait is masked.

Homozygous and Heterozygous

Homozygous	Heterozygous
It is a pure trait and true-breeding i.e., gives rise to similar or homozygous individuals.	It is hardly pure and produces offspring with different genotypes on selfing e.g. RR, Rr and rr upon selfing of Rr individuals.
Both of the alleles are similar, e.g., RR, rr	Alleles are not similar, e.g. Rr
Individuals can carry either dominant or recessive alleles but not both at once.	Individuals can carry both dominant and recessive alleles at once.
It produces one type of gamete.	It produces two types of gametes.

Haploid and Diploid

Animal and plants have two type of cell; **haploid cells** and **diploid cells**.

Haploid cell: a cell with only one chromosome from each homologous pair with only one gene for each trait.

Diploid cell: a cell with the full set of homologous chromosomes with two genes coding for each trait.

Monohybrid Cross

As learnt in Year 11 genetics, a monohybrid cross shows a cross between pure breeding parents showing alternate (opposite) forms of one trait.

Example:

A cross between pea plant that is:

- homozygous for yellow seed (**YY**) where, **Y** is the *dominant* allele.
- homozygous (**yy**) for green seeds where, **y** is the *recessive* allele.

Parent Generation: **YY** x **yy** therefore, gametes = **Y** , **Y** , **y** , **y**

F1 generation:

	Y	Y
y	Yy	Yy
y	Yy	Yy

F1 generation will produce 100% heterozygous (**Yy**) seeds which will be Yellow in colour.

F2 generation:

(selfing the heterozygotes from F1 generation) = **Yy** x **Yy** therefore, gametes = **Y** , **y** , **Y** , **y**

	Y	y
Y	YY	Yy
y	Yy	yy

F2 generation will produce: 1 **YY** , 2 **Yy** and 1 **yy**

= 3 Yellow seeds and 1 Green seed.

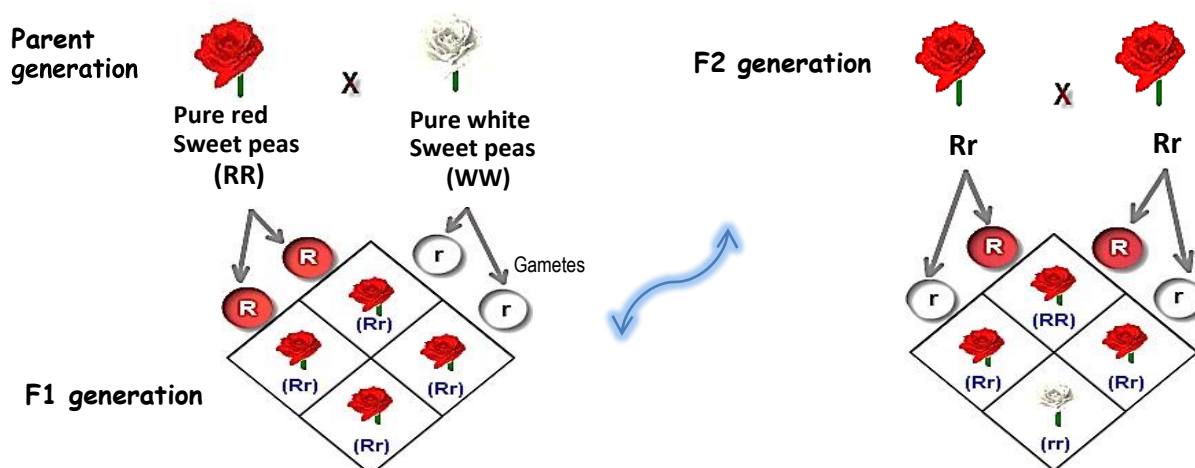
= the ratio is **3:1**

Genetic Continuity

Genetic continuity describes the maintenance of the number and the type of genes in the daughter cells as identical to the parental (original) cells that went under cell division. Genetic continuity ensures that new cells or organisms have enough genes to survive thus, preserving genetic information across generations.

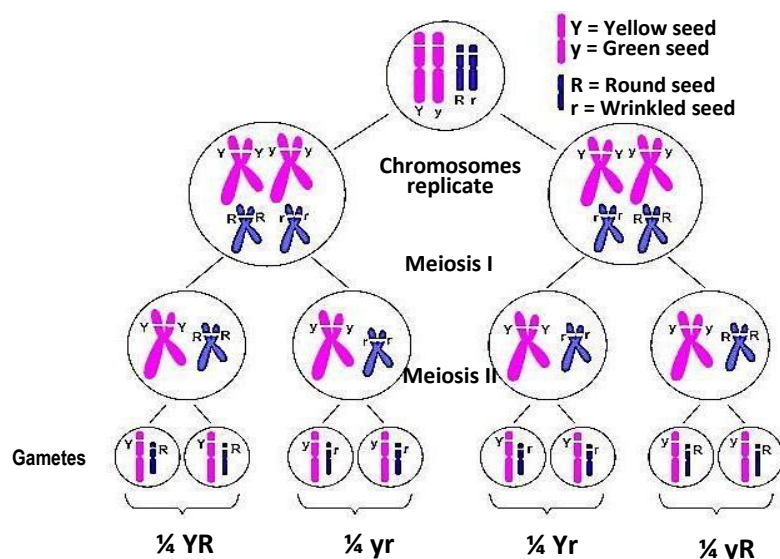
Law of Segregation (Mendel's 1st Law)

According to Gregor Mendel (Father of Genetics), allele pairs segregate (separate) randomly from each other during production of gametes. A sperm or the egg carries only one allele for each inherited trait. When sperm and egg unite during *fertilisation*, each contributes its allele, restoring the paired condition in the offspring.



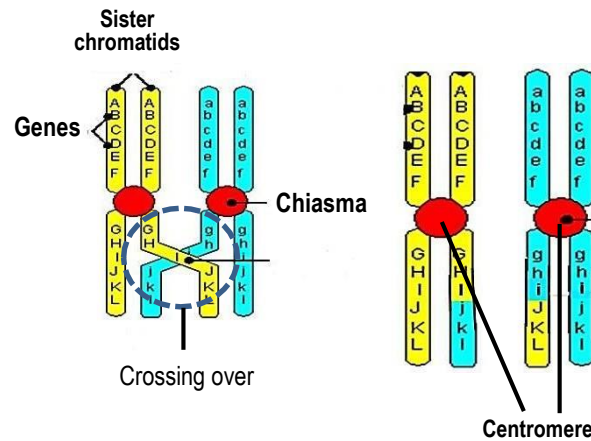
Law of Independent Assortment (Mendel's 2nd Law)

The Law of Independent Assortment also known as '*Inheritance Law*', states that alleles of different genes for separate traits are passed independently of one another from parents to offspring during gamete formation. It takes place in eukaryotes during *metaphase I of meiosis* ensuring formation of a gamete that has a mixture of chromosomes from both parents.



Gene Recombination/ Crossing Over

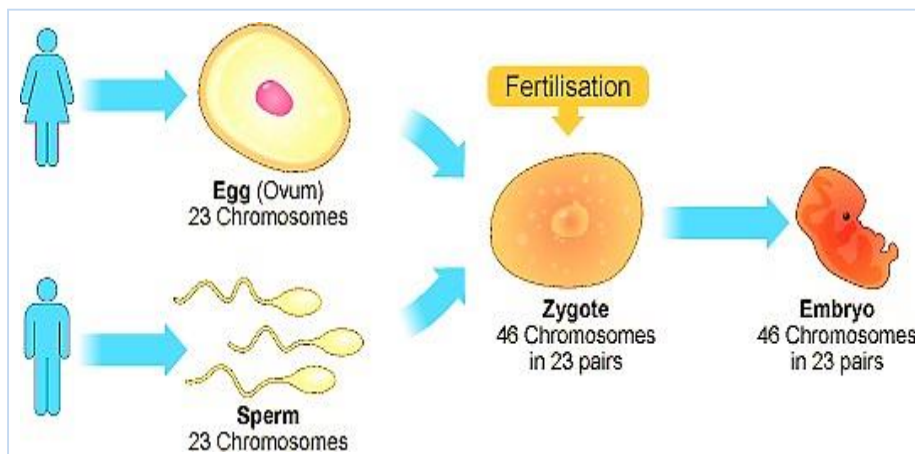
Genetic recombination is the genetic transmission by which the combinations of alleles observed at different loci in two parental individuals become shuffled in offspring individuals. During meiosis, homologous chromosomes (1 from each parent) pair along their lengths. The chromosomes cross over at points called **chiasma**. At each chiasma, the chromosomes break and re-join, trading some of their genes. This phenomenon is known as gene recombination or crossing over.



Source: www.yourarticlelibrary.com

Random Fertilisation

A male gamete can fertilise any of the female gametes. The fertilization between a male gamete and a female gamete occurs randomly in the fallopian tube. Since, each gamete has a unique set of combination of genes, every zygote formed is unique. This leads to genetic variation due to the different combination of genes from the male and female gamete.



NB: Segregation, independent assortment, crossing-over increase and random fertilisation maintain genetic diversity.

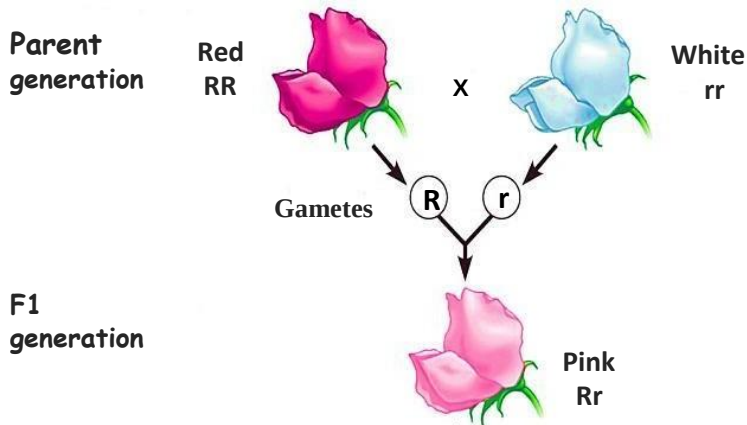
Source: <http://www.bbc.co.uk/staticarchive/>

Types of Dominance

As learnt in Year 11, one allele is completely dominant over another. In Year 12, we will consider alleles for traits that show lesser degrees of dominance.

Incomplete Dominance

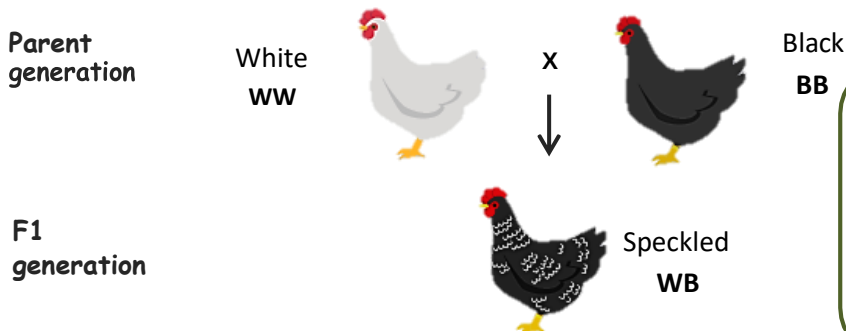
With incomplete dominance, a cross between organisms with two different phenotypes produces offspring with a **third** phenotype that is a '*blending of the parental traits*'.



➤ It's like mixing paints, red + white will make pink. Red doesn't totally block (dominate) the pink, instead there is incomplete dominance, and we end up with something in-between.

Co-dominance

Co-dominance is a heterozygous condition in which both alleles for a gene are expressed in the phenotype, with neither being dominant or recessive to the other.



➤ It's like mixing marbles, white + black gives a mixture of both black and white. Neither of the colours dominate but both are distinct.

Blood typing is a common example of co-dominance where people have type A and type B or they can have a combination of both type AB. Alleles for A blood and allele for blood B are co-dominant to each other, therefore, if both are present they are expressed equally in the phenotype as AB blood.

(NB): Blood O is recessive to both A and B alleles.

Multiple Alleles

Humans have of four blood types (A, B, AB, O) resulting from 2 or more allele combinations.

A number greater than 2 alleles is represented differently from the common practice of capital letter for dominant traits and small letter for recessive traits.

For blood type, co-dominant alleles, capital 'I' carries the co-dominant allele as a superscript (like I^A and I^B), while small letter 'i' carries the recessive O allele like 'i'.

Genotype	Phenotype
$I^A I^A$ or $I^A i$	Type A blood
$I^B I^B$ or $I^B i$	Type B blood
$I^A I^B$	Type AB blood
ii	Type O blood

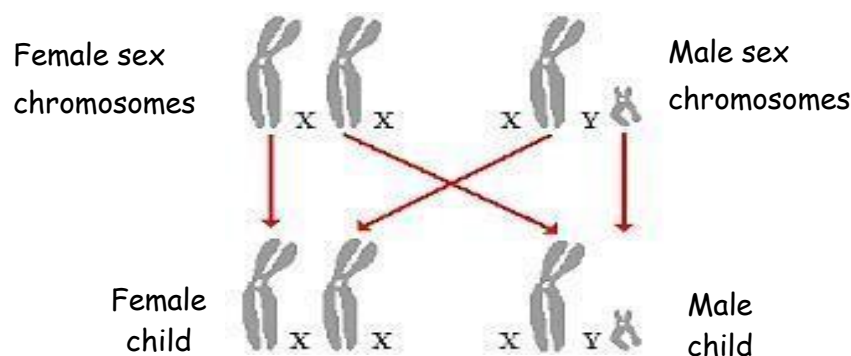
NB: Each organism inherits only two alleles regardless of the number of alleles present for a trait.

Sex-linked genes

- Genes that are carried by either **X** or **Y** sex chromosome are said to be **sex linked**.
- Some of the well known sex-linked conditions are colour-blindness and haemophilia.
- The genes causing the two mentioned conditions are recessive in nature.
- Another example of a sex-linked condition is baldness in men which causes them to lose hair or thinning of the hair on the crown of the head.
- The gene for baldness in men is sex-linked and is carried on the Y chromosome.

Men normally have an 'X' and a 'Y' combination of sex chromosomes. Women have two X chromosomes.

Since only men inherit Y chromosomes, they are the only ones to inherit **Y-linked** traits. Men and women both can get the **X-linked** traits since both inherit X chromosomes.



Source: <http://anthro.palomar.edu/biobasis/bio>

In women, a recessive allele on the X chromosome is often masked in their phenotype by a dominant allele on the other chromosome. This is one reason why women are frequently carriers of X-linked traits and rarely have the recessive allele expressed in their phenotypes. On the other hand, men only have one X chromosome. Therefore, genes on the X chromosome that do not code for gender are usually expressed in the male phenotype even if they are recessive since there are no corresponding genes on the Y chromosome in most cases.

Note:

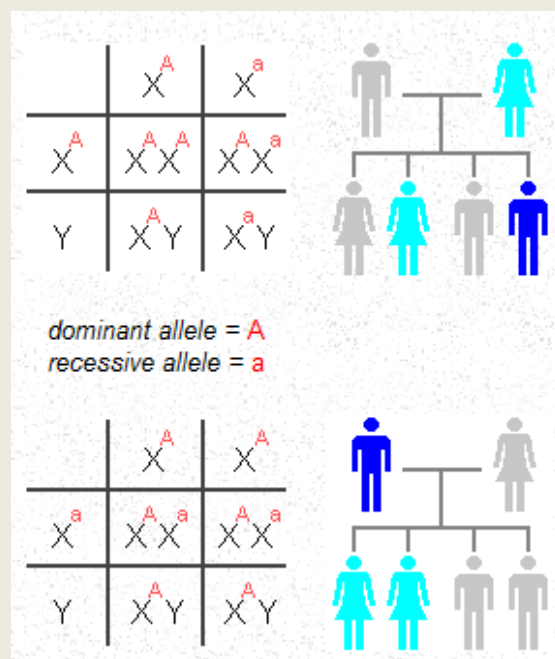
If a woman is a carrier of an X-linked recessive allele for a disorder and her partner is normal;

- All of their sons will have a 50% chance of inheriting the disorder.
- None of the daughters will inherit the disorder, but half of them are likely to be carriers.

If a man has an X-linked recessive disorder and his partner does not carry the allele for that disorder;

- All of their daughters will be carriers.
- None of their sons will inherit the harmful allele.

Source: <http://anthro.palomar.edu/biobasis/>



Dihybrid Cross

A **dihybrid** cross occurs between parents which are true-breeding for contrasting forms of two traits (characteristics).

- ❖ It is the simultaneous inheritance of two traits.
- ❖ To show a dihybrid cross Mendel had used true-breeding pea plants, i.e. homozygous for seed shape and seed colour.
- ❖ His results of the cross were; one strain of plant produced smooth, round, yellow coloured seeds, while the other produced wrinkled, green coloured seeds.

Example:

RR = homozygous dominant for smooth coat or shape

rr = homozygous recessive for smooth coat or shape or in other words (wrinkled seeds)

YY = homozygous dominant of yellow colour

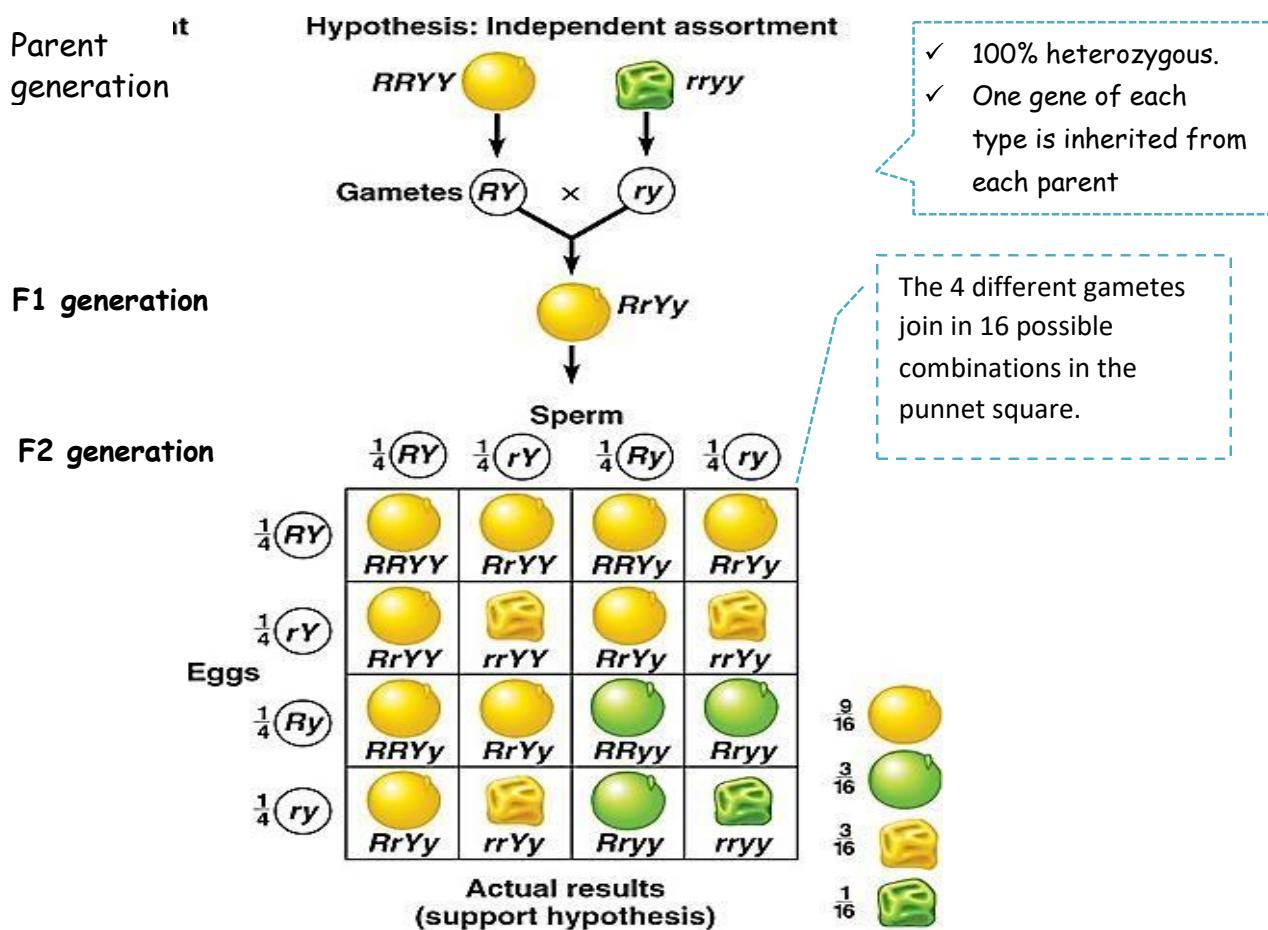
yy = homozygous recessive for yellow coat colour or in other words (green seeds)

- Parent generation (genes in parents) = **RRYY** and **rryy**
- Genes in gametes = **RY** and **ry**
- Genotype of F1 generation would be = **RrYy** (100 %)

Now what would be the genotype of the gametes produced the F1 generation?

- Since the two genes for seed colour and seed shape are not on the same chromosome, the chance of inheriting **R** or **r** is not affected by the chance of inheriting **Y** or **y**.
- Each gamete would receive only one gene for shape, i.e. **R** or **r** and only one gene for colour, i.e. **Y** or **y**.
- Mendel's law of Independent Assortment applies here.
- Hence, all possibilities must be considered.
- If independent assortment is occurring then a cross shown below is expected.

In a monohybrid and a dihybrid cross, the entire F1 generation is always heterozygous



In a dihybrid cross, the following probable phenotypic ratio always expected in the F2 generation:
9 for both dominant traits: 3 dominant for one trait: 3 dominant for the other trait: 1 recessive for both

The phenotypic ratio of the F 2 generation is:

9:3:3:1

9 smooth yellow seeds
3 smooth green seeds
3 wrinkled yellow seeds
1 wrinkled green seed

VARIABILITY

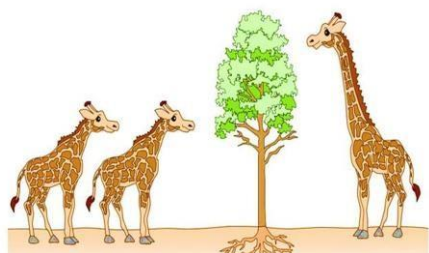
Variability or genetic variability is the potential for a characteristic to vary within a population. This is different from genetic variation because instead of measuring the actual variation within a population, genetic variability measures how much the trait will vary. Genetic variability is directly related to biodiversity and evolution, because a population needs enough variability to be able to adapt and evolve to environmental changes.

Example:

The giraffe population

Genetic variation = different length necks; short, medium length, long

Variability = how much the neck length tends to vary within the population.



Source: <http://www.vce.bioninja.com.au/>

- High variability will allow the population to adapt to environmental changes (like the branch height).
- Low variability means that population will not be able to adapt to new branch heights and will risk extinction.

NB: Genetic diseases (resulting from mutations) also cause genetic variation.

Processes leading to Variability

Sexual Reproduction

- ❖ In sexually reproducing animals, most of the genetic variation in a population results from the unique combination of alleles that each individual receives.
- ❖ At the nucleotide level, all the difference among these alleles have originated from past mutations but the mechanism of sexual reproduction shuffles existing alleles and deals them at random to determine individual genotype.

1. Meiosis I and II

During mitosis, each chromosome is copied, resulting in two identical sister chromatids. These joined chromatids later separate by cytokinesis to form the next generation of identical chromosomes.

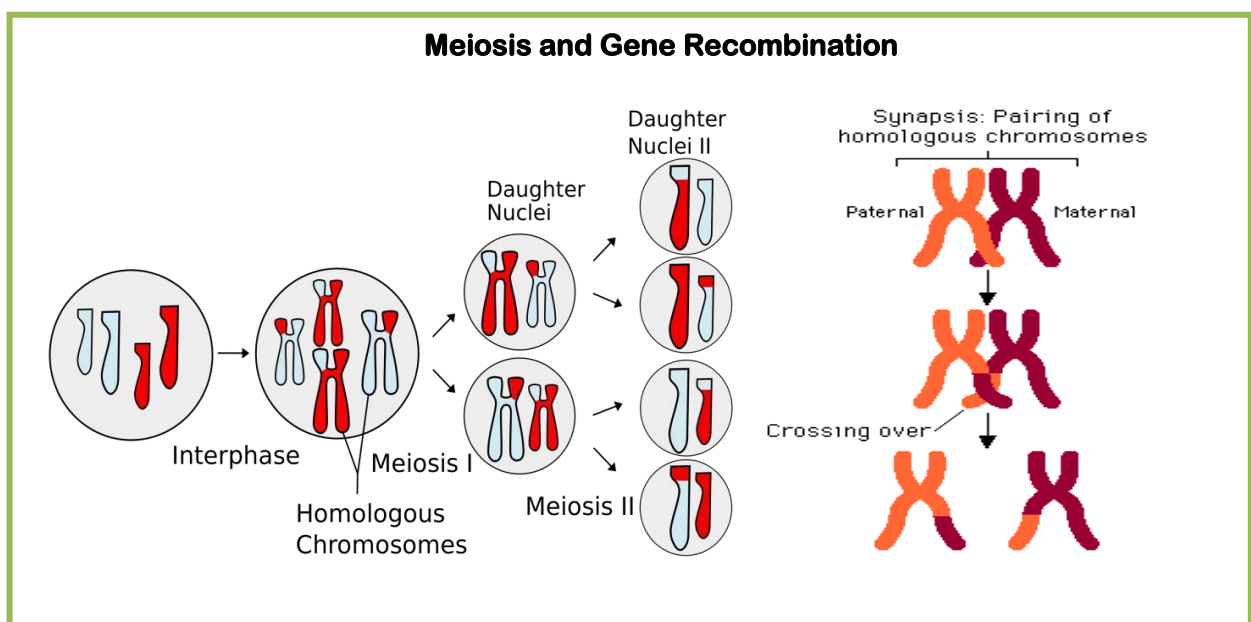
In meiosis I;

- chromatids do not separate, thus each daughter cell receives only one copy of each chromosome (haploid number of chromosomes).
- each copy contains two chromatids and the distribution of each chromosome is random.
- these chromatids then separate in meiosis II and are distributed to each resulting gamete.

Since duplicated chromatids remain joined during meiosis I, **each daughter cell receives only one chromosome of each homologous pair**. This reduces the diploid number to haploid. This means that it is equally likely for a given chromosome to be distributed to either of the two daughter cells. By shuffling the genetic deck in this way, the gametes resulting from meiosis II have new combinations of maternal and paternal chromosomes, thus, increasing genetic diversity.

2. Gene recombination

- ❖ Gene recombination (also called ‘crossing over’) as seen earlier, occurs during prophase of meiosis I. This is when the homologous pairs of chromosomes cross over with each other and often exchange chromosome segments.
- ❖ This recombination allows mixing of the genes from the two parents hence, creating genetic diversity by allowing genes from each parent to intermix.
- ❖ Crossing over occurs between non-sister chromatids. Due to the interaction of genes with each other, the new combination of genes on a chromosome leads to new traits in offspring resulting in variability or genetic diversity.



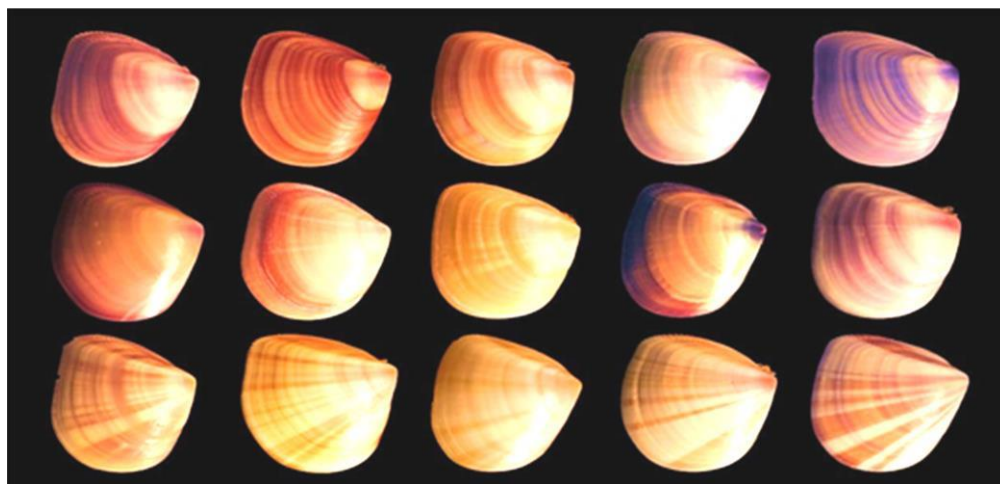
3. Mutation (genetic)

During replication, an organism's genetic make-up (DNA) can change or mutate. Changes to genes are called mutations.

Effects of Mutation

- ❖ If mutation is **large** then the organism will probably not survive to reproduce.
- ❖ If mutation is **small** then change may be beneficial.
 - Offspring will flourish, doing better than others in that species.
 - More offspring will inherit this beneficial mutation and will be better suited for survival in their natural environment through natural selection.
- ❖ Mutations may have **no effect**. For example, the protein that a mutated gene produces may work just as well as the protein from the non-mutated gene.
- ❖ Mutations may sometimes be **helpful** but they are often harmful. For example, haemophilia is an inherited disorder that stops blood from clotting properly. It is caused by a mutated gene.
- ❖ Genes can be switched on and off. In any one cell, only some of the full set of available genes are used. Different types of cells produce different ranges of proteins. This affects the functions they can carry out. For example, only pancreas cells switch on the gene for making the hormone insulin.
- ❖ Mutations to genes can alter the production of certain proteins, or even prevent them being made by a cell.

Example:



The diagram above shows phenotypic variation in the shell of *Donax variabilis* (coquina mollusk)

Source: <https://www.boundless.com>

Genetic Disorders

- A genetic disorder is a disease caused by an abnormality in an individual's DNA.
- Abnormalities can be as small as a single-base mutation in just one gene, or they can involve the addition or subtraction of entire chromosomes.
- Chromosomes contain genes that pass on hereditary traits from parents to children.
- Many animals, including humans, have two types of chromosomes: **autosomes** and **sex chromosomes**.
- Normally, humans have a total of 46 chromosomes in each cell (22 pairs of autosomes and 1 pair of sex chromosomes)
- Sex chromosomes determine the sex or gender of an individual.
- The combination of the X and the Y chromosome determines the sex of a child.
- Females have two X chromosomes (the XX combination); males have one X and one Y chromosome (the XY combination).
- Autosomes are all the rest of the chromosomes that are not needed for sex determination.

There are two major forms of genetic disorders; either due to abnormal number of autosomes or sex chromosomes.

The three types of disorders that we will study are:

1. Downs Syndrome (autosomal)
2. Turner's Syndrome (sex chromosome)
3. Klinefelter's Syndrome (sex chromosome)

Down Syndrome (Trisomy 21)	
Condition / Cause	Physical Effects
– The person has three copies of chromosome 21. – Caused by failure of the 21st chromosome to separate or due to abnormal cell division during development of egg or sperm. – Presence of an extra 'chromosome 21', results in each body cell having a total of 47 chromosomes. – Since there are 3 of chromosome 21 (trisomy), the disorder is also known as Trisomy 21.	- Characteristic facial features (small chin, slanted eyes, flat nasal bridge, protruding tongue, small mouth) - Physical growth delay - Short stature - Heart defects - Susceptibility to respiratory functions. - Mental retardation. - Shorter life-span than normal. - Most are sexually-underdeveloped/ sterile

Klinefelter's Syndrome (XXY)

Condition / Cause	Physical Effects
– Affects males only. – People with this condition are born with an extra 'X' chromosome resulting in males having XXY sex chromosome. – They enter normal puberty but by mid puberty they tend to have low levels of testosterone causing formation of small testicles and inability to make sperm. – Few or no sperm cells. – This condition is not inherited from parents.	– Affected males also have learning disabilities and behavioural problems such as shyness and immaturity. – Increased risks of certain health problems. – Children with this condition frequently have difficulty with language, including speech, reading and writing. – Approximately, 50% of males with this condition are dyslexic (i.e. inability to read and write). – Depressed or have poor judgement in stressful situations. – Nervousness especially amongst social crowd.

Turner's Syndrome (monosomy or having only one X chromosome)

Condition / Cause	Physical Effects
– Genetic disorder that occurs in girls where instead of the two X chromosomes to define the gender as female, one of the X chromosomes is missing. – Girls with this condition undergo abnormal puberty. – They have incomplete sexual development.	– It causes them to be shorter. – Average height of an adult with this condition is 4 feet, 8 inches. – Puffy hands and feet at birth. – Wide shoulder – Broad chest – Webbed neck – Low hairline at the back of the neck – Increased number of small moles on the skin – Deep set nails. – Problems with heart, kidney and thyroid glands. – Middle ear infection and skeletal problems.