BIOLOGY

FOR ALL

Year 12

TEXT BOOK

Ministry of Education

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PREFACE

The development of this Textbook was entirely based on the Year 12 Syllabus.
It has three strands: (1) Structure and Life Processes; (2) Living Together and (3) Biodiversity, Change and Sustainability.

The contents of this book have been simplified so that it can be used by all students of different capabilities. It contains very useful materials to help students and teachers to prepare for the Fiji Year 12 Certificate Examination.

It is confidently believed that it will furnish Year 12 students with the necessary number and variety of exercises essential to successful instructions in biology.

All examples that have been introduced can even be attempted by an average pupil without assistance. They have been carefully graded to suit the slow learners as well while there are some problems that are provided for advance learners.

Teachers and students are also advised to use other resources for enhancing of teaching and learning. This textbook is just a guide to accomplish the learning outcomes.

ACKNOWLEDGEMENT

Throughout the process in writing this textbook, a number of people have sacrificed their valuable time to assist the Ministry of Education. They must be acknowledged for their active participation and without their insights, guidance and continued support; this book may not have been possible.

The Ministry of Education, therefore, hereby acknowledges the following people for their valuable contributions to this book:

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STRAND 1

YEAR 12

SUB-STRAND 1.1

CELLULAR ORGANISATION

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	
 Z. Janssen	**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.
 A. van Leeuwenhoek	**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.
 E. Abbe	**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
 F. Zernike	**1932** – Frits Zernike invents the phase-contrast microscope that allows the study of colourless and transparent biological materials. The Nobel Prize in Physics 1953
 E. Ruska	**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
 G. Binnig and H. Rohrer	**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*

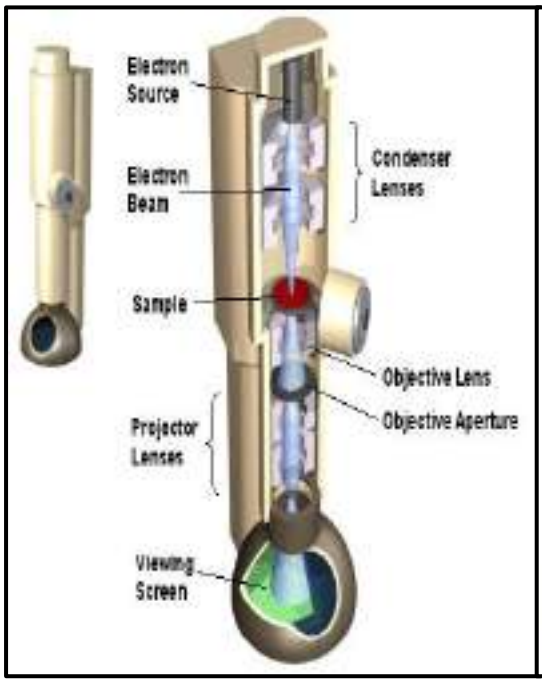
2. Dissecting Microscope

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.

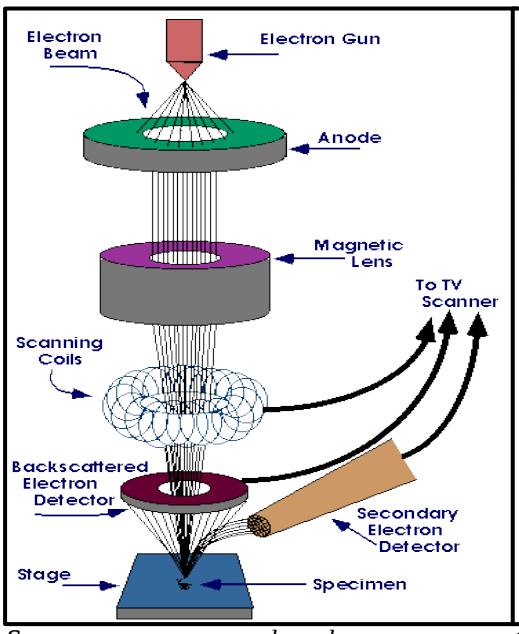


Source: *www. barrett-group.mcgill.ca*

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. www.purdue.edu*

Source: *www. www. gallery.asiaforest.org*

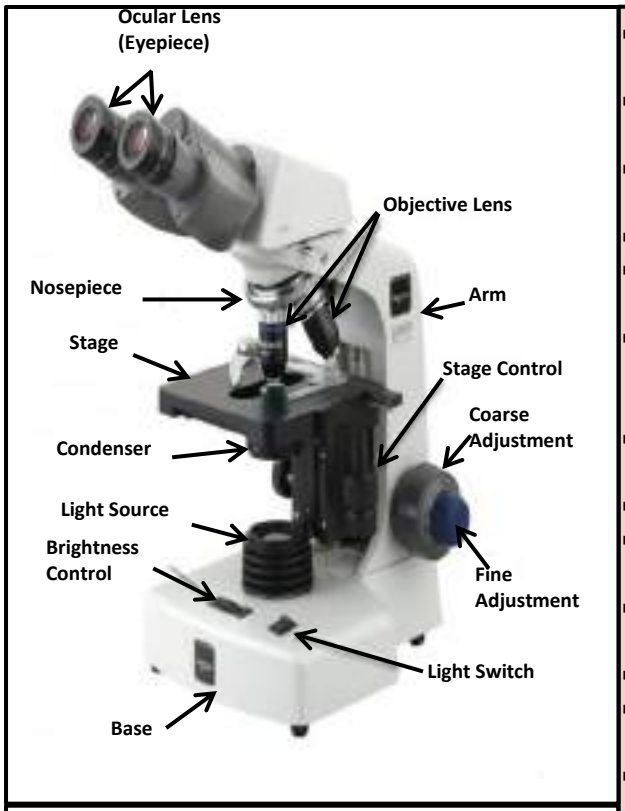
(iii) Scanning Transmission Electron Microscope (STEM)

- 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

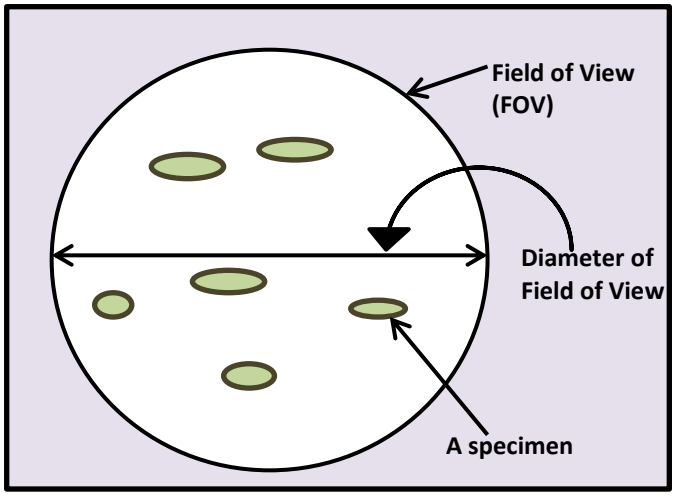
Parts of a Compound Microscope and the Respective Functions



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

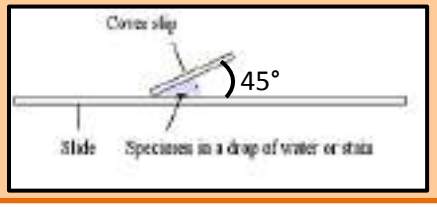


Approximate Diameter of the FOV (Eyepiece Lens: 10X)		
Objective Lens	**Total Magnification**	**Diameter (mm)**
4X	40X	4.5
10X	100X	1.8
40X	400X	0.45
100X	1000X	0.18

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 45º 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:

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

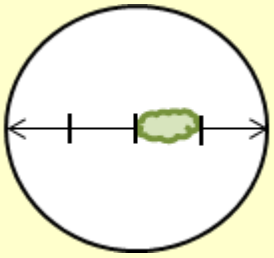
$$\text{Diameter of FOV at High Power} = \frac{40\text{X}}{400\text{X}} \times 4 \text{ mm}$$

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

Estimating Cell Size

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

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

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

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

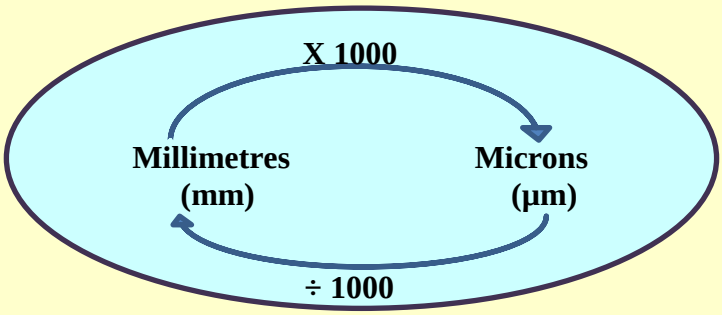
Step 2: Estimate the cell size using the formula

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

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

Estimating Cell Size Continued

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



Size of the specimen in (µm) = 0.1 mm × 1000
= 100 **µm**

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 accidently 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.

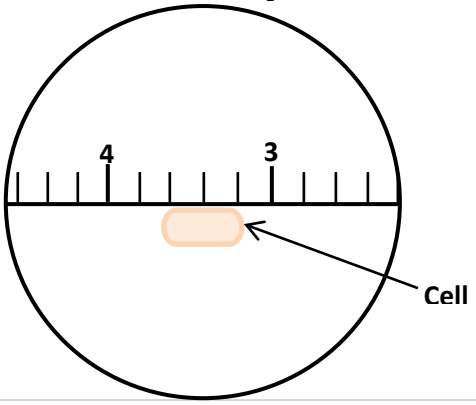
Storing Microscopes

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

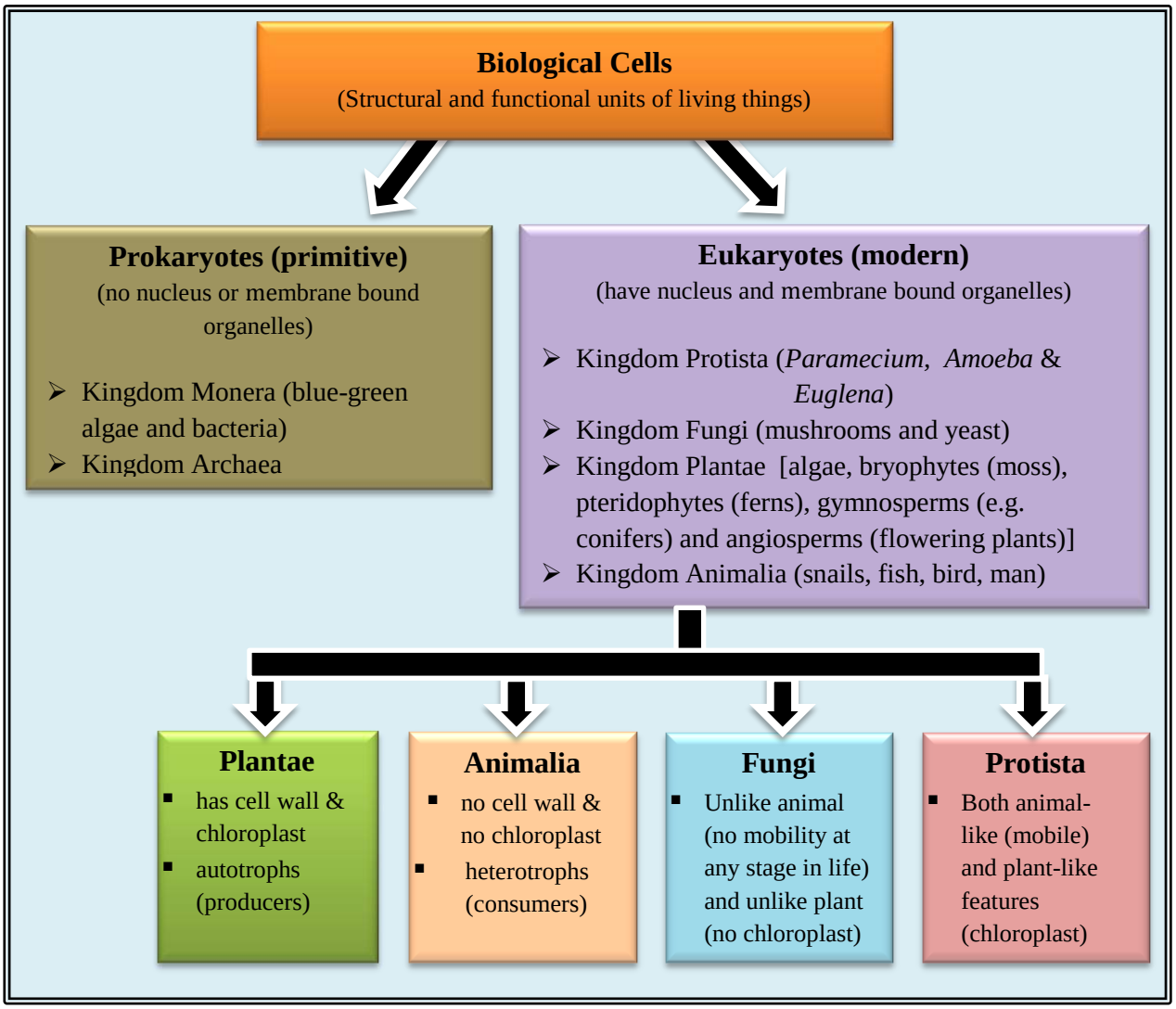
- The word **Prokaryotes** is derived from the ancient Greek where '*pro'*= 'before' and '*karyon'*= 'nut or kernel'.
- These organisms lack an organised cell nucleus or any other membrane-bound cell organelles. Most are unicellular, but some prokaryotes are multicellular.
- Example: Archaea (microorganisms 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.

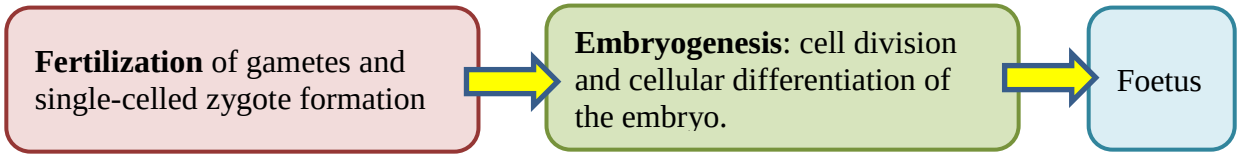
The major differences between both are:

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 whiles the skeleton system in foetal stage.
- For this Year, we will only concentrate on the processes involved in embryogenesis.

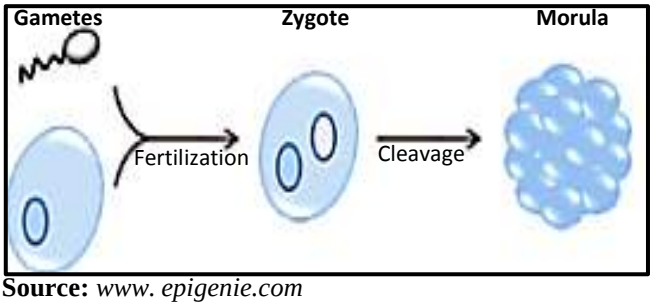


Process in Embryogenesis

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**.

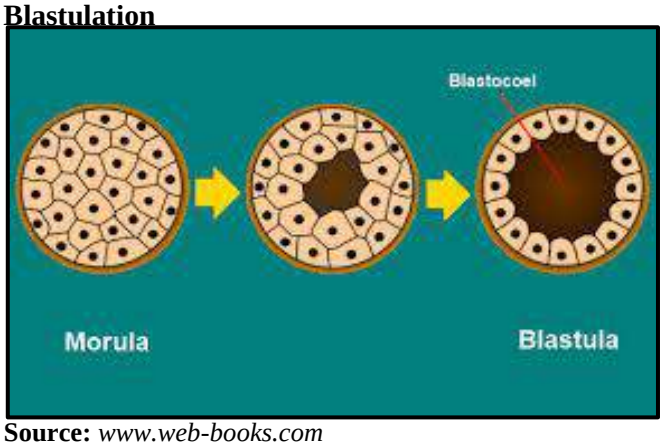


Source: *www. epigenie.com*

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

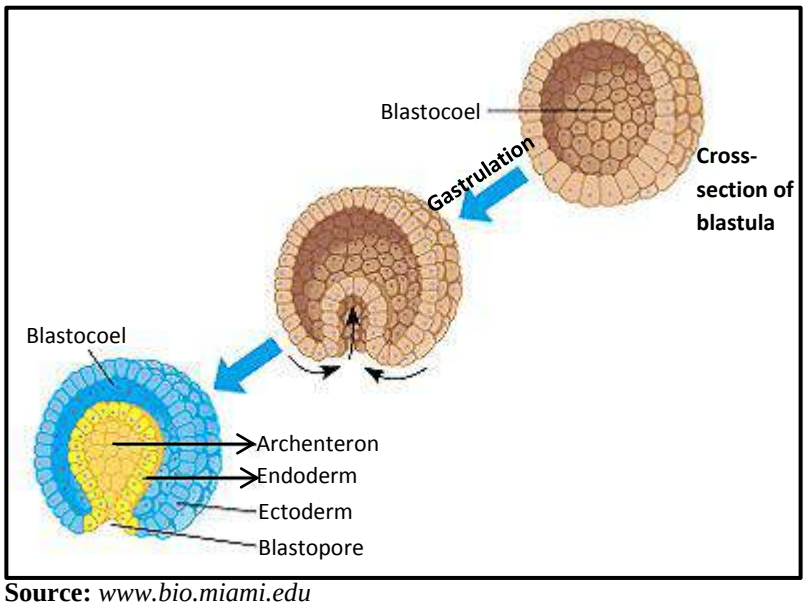


Source: *www.web-books.com*

Gastrulation

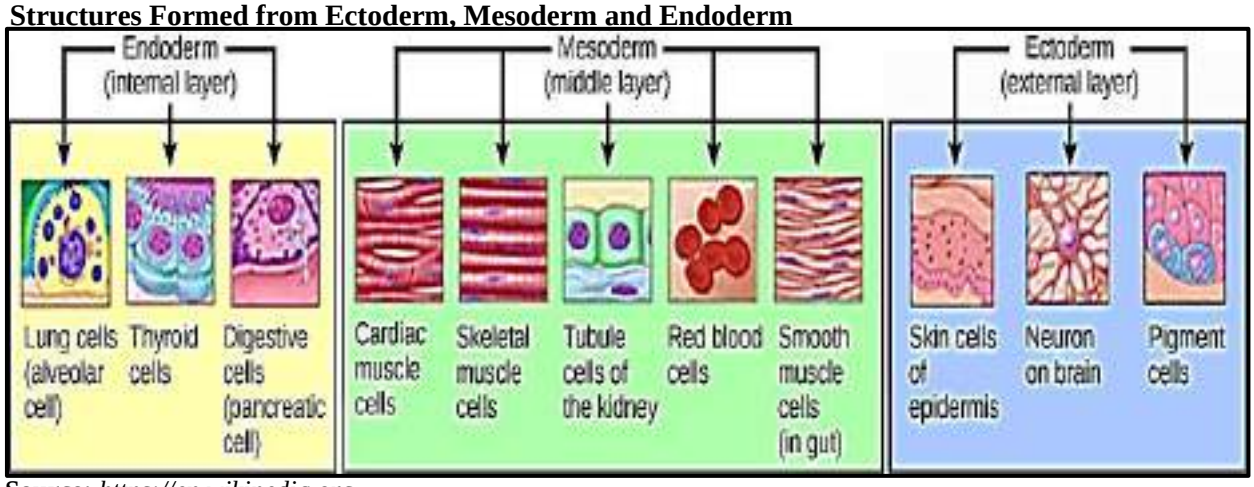
- Stage in which cell movements result in a massive reorganization of the blastula into three layered structure known as the **gastrula**.
- The differentiation of the gastrula into the three germ layers results in ectoderm, mesoderm, and endoderm.
- Gastrulation involves changes in cell motility, cell 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

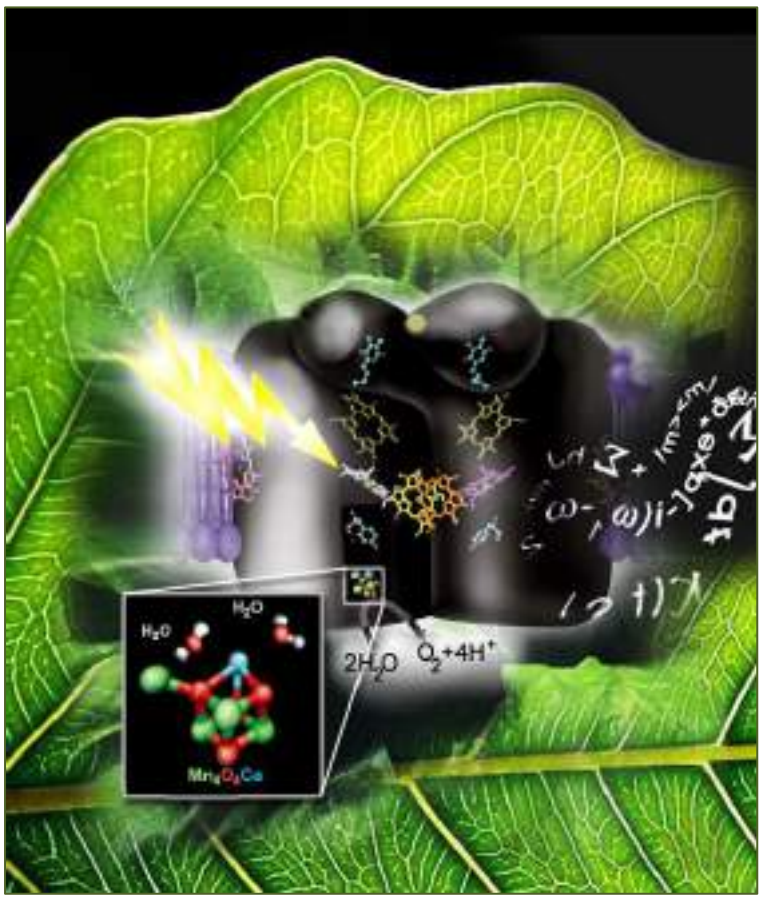
14. Identify three types of changes the cells experience in gastrulation.

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:

$$\underset{\text{6 Carbon dioxide}}{6CO_2} + \underset{\text{6 Water}}{6H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} \underset{\text{6 Glucose}}{6C_6H_{12}O_6} + \underset{\text{6 Oxygen}}{6O_2}$$

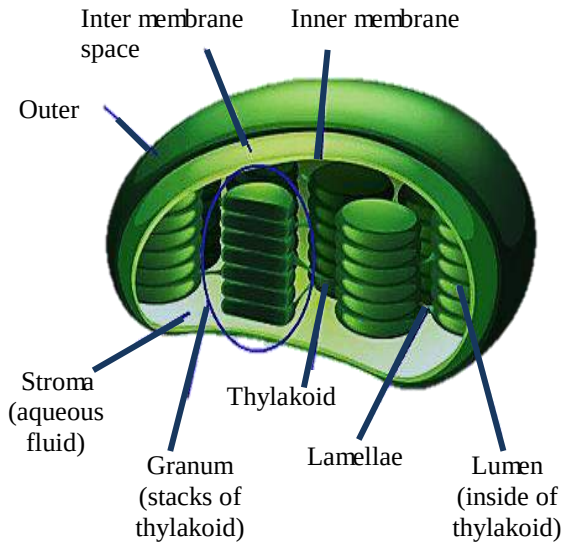
Key Ingredients for Photosynthesis

- **Carbon dioxide** – diffuses through the leaf stomata. The air spaces in the leaf allows CO_2 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 absorbs 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.

Chloroplast



Function of the Structures

- Chloroplast has 2 membranes: **inner** and **outer membrane**.
- Inner membrane surrounds the stroma and the grana.
- **Grana** are stacks of thylakoid.
- Single stack of thylakoid= **granum**.
- Chlorophyll sits on top of each **thylakoid**.
- Grana are connected by lamellae.
- **Stroma** is the empty space in the chloroplast just like the cytoplasm in cell.

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.

$$2H_2O \xrightarrow[\text{Energy}]{\text{Light}} 4H^+ + O_{2\,(\text{waste})} + \text{Electrons}$$

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*

High energy e^- ⟶ low energy e^- + ATP

- **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.

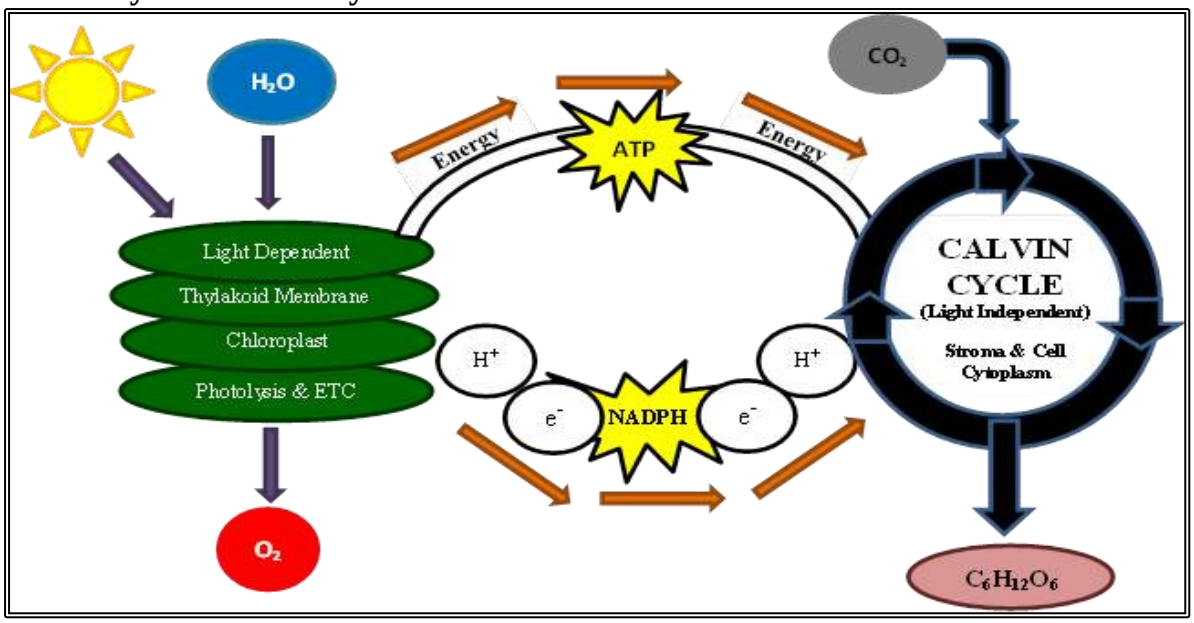
- In eukaryotes (plants) **non-cyclic photophosphorylation** occurs. This is accomplished by splitting the water molecule, converting ADP to ATP, and the provision of the reduced coenzyme NADPH to power the synthesis of energy storage molecules.

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**.

$CO_2 + H_2$ (from NADPH) + energy (from ATP) ⟶ $C_6H_{12}O_6$

Summary of the Photosynthesis Reaction



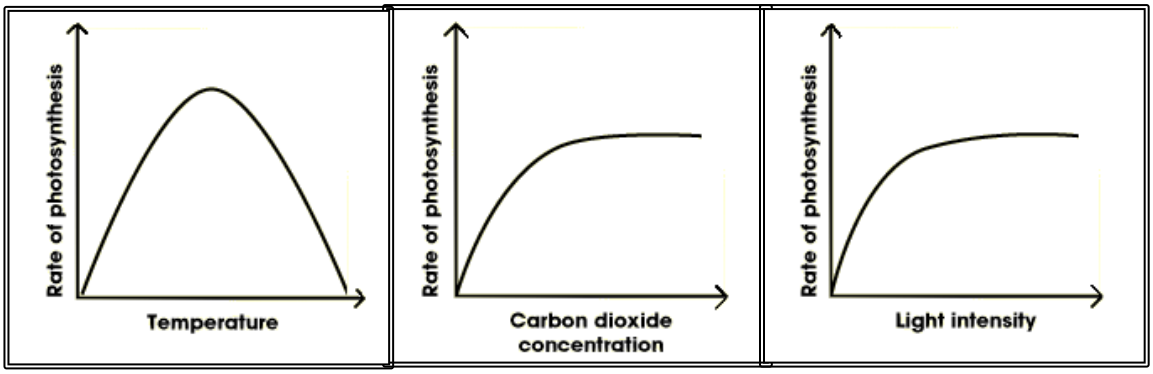
Factors Affecting the Rate of Photosynthesis

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 (CO_2) Concentration** – Increase in the carbon dioxide concentration will also increase photosynthesis since carbon gets incorporated as carbohydrate ($C_6H_{12}O_6$).

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 CO_2 since CO_2 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.

BI 12.1.2.2 RESPIRATION

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:

$$6C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Glucose + Oxygen → Carbon dioxide + Water + ATP

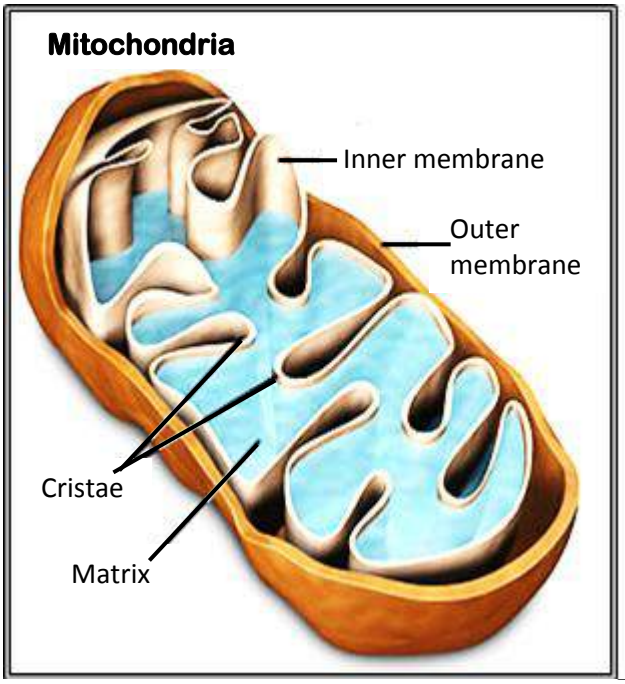
Key Ingredients for Aerobic Respiration

❖ **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

$C_6H_{12}O_6 \longrightarrow$ 2 Pyruvate + Little Energy (ATP)

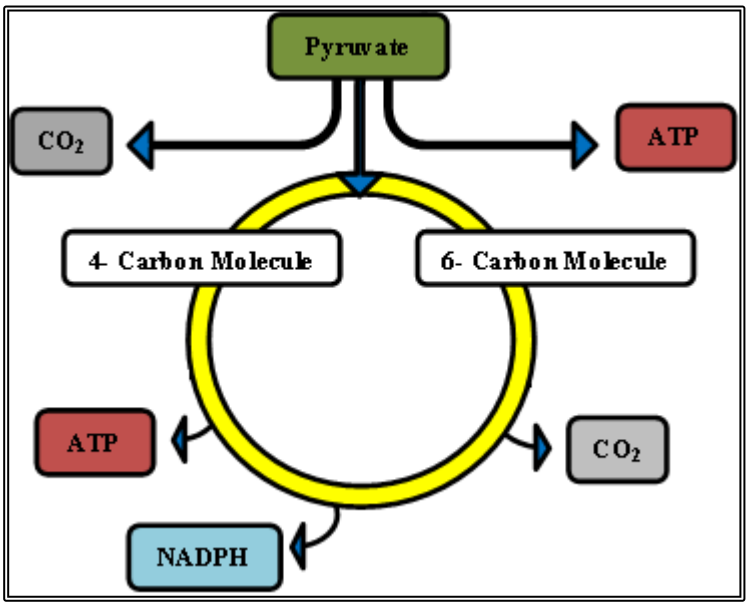
Stage 2: Krebs Cycle

- 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)

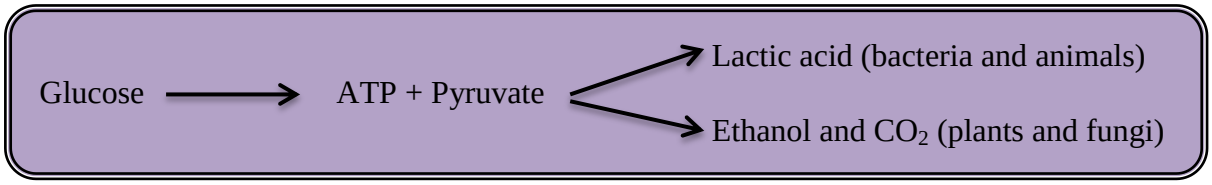
- Similar to the ETC in photosynthesis.
- Majority of the energy contained in the glucose molecule is released.
- High energy electrons from Krebs cycle move back and forth across the cristae until all its energy has been released into the ATP molecules.
- After all the energy is released from the electrons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

$$4\,H^+ \text{ (carried by NADPH) } \&\ 4 \text{ high energy } e^- + O_2 \longrightarrow 2H_2O + \text{Energy (carried by ATP)}$$

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

1. Which organisms contain chloroplasts?
2. Where does the plant get energy to make its food?
3. What is the process conducted by the producers?
4. What are the raw materials (reactants) used for photosynthesis?
5. Which simple sugar is produced in photosynthesis?
6. Which gas is used and which is released in photosynthesis?
7. Which part of the plant contains most of the photosynthetic cells?
8. Where in the chloroplast (organelle) is chlorophyll (pigment) found?
9. What is the role of stomata in photosynthesis?
10. 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?
11. What are stacks of thylakoid known as and how are these stacks connected?
12. 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.

BI 12.1.2.3 CHEMICALS OF LIFE

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

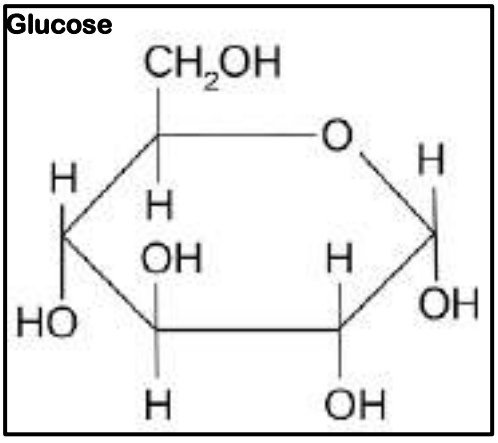
- Simple sugar molecules made of carbon, hydrogen and oxygen atoms.
- It can be linked into long chains to form complex carbohydrates.
- Simplest sugar ring is known as monosaccharide (mono - one; saccharide - sugar).
- Some carbohydrates can be made from joining two (disaccharide) or more (polysaccharide)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

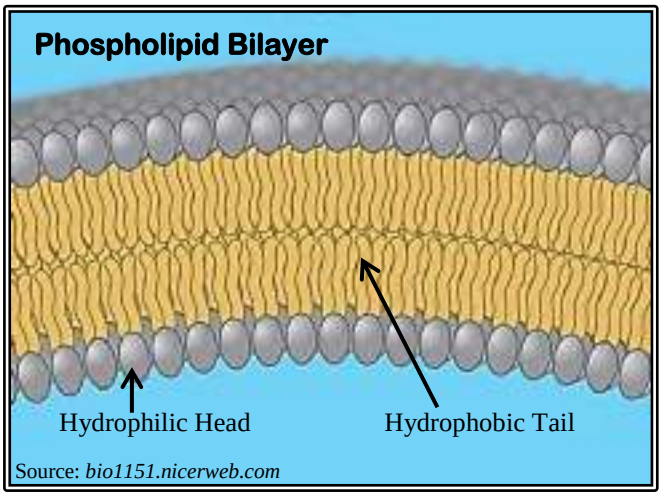
iv. **Chitin**- a polysaccharide found in the cell wall of fungi, exoskeleton of the arthropods and radula of the molluscs.

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	Unsaturated Fat
▪ No double bonds between carbons ▪ Solid at room temperature ▪ Mostly animal fats ▪ Excess consumption contributes to NCDs ▪ Examples: butter	▪ Double bonds between carbons ▪ Liquid at room temperature ▪ Mostly vegetable fats ▪ Not unhealthy in moderate consumption ▪ Example: soya bean oil

3. PROTEINS

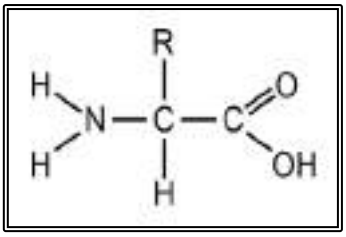
Source: *www.rivertea.com*

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).

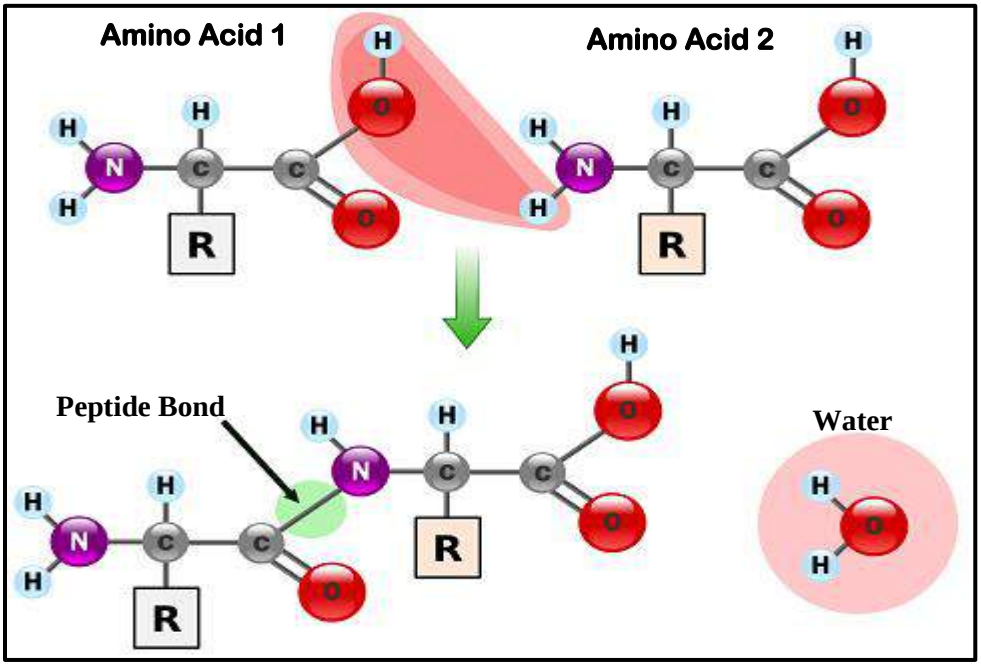
Basic amino acid structure

- Carbon centre
- COOH- carboxylic acid group
- NH_2- 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*

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

Source: *www.godandscience.org*

- 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)

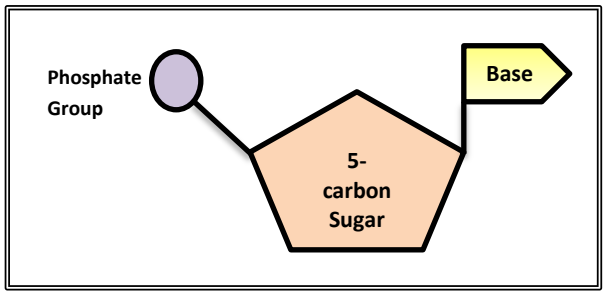
Double helix structure

Source: *www.bio.miami.edu*

Structure

- Nucleotides are subunits which build the nucleic acids.

- Each nucleotide has 3 parts:
  1. Phosphate group
  2. 5-carbon sugar
  3. Organic base

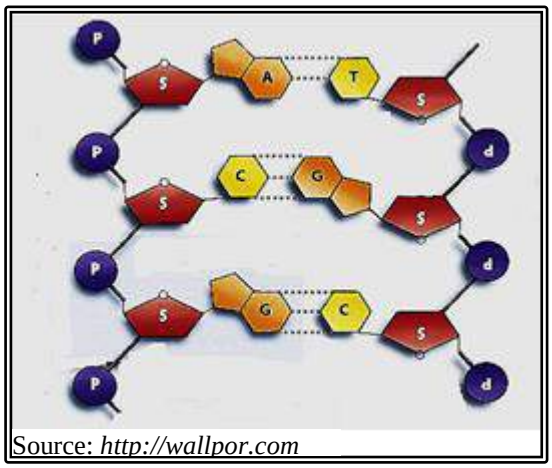


Structure and Function of DNA

- ❖ 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).



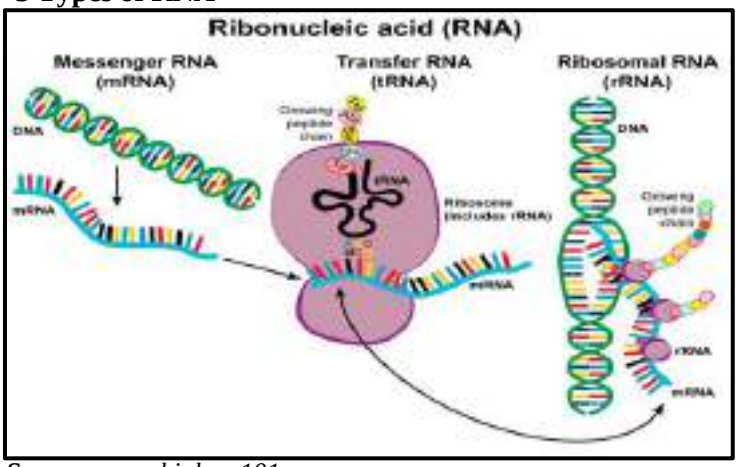
Source: *http://wallpor.com*

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 ❖ Has deoxyribose sugar ❖ Thymine (nitrogenous base)	❖ Single stranded ❖ Has ribose sugar ❖ 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

8. Carbohydrates have many functions in the cell. Which of the following is an incorrect match of the carbohydrate with its function?
   A. Sugar transport in plants: disaccharides
   B. Energy storage in plants: starches
   C. Energy storage in plants: lactose
   D. Sugar transport in humans: glucose

9. Identify the complementary DNA and mRNA base orders for the following single DNA strands given below?
   A. TACTCGGCTA
   B. GCTAGCTAA
   C. AACTGCACAT
   D. TACGGCATC

10. Proteins serve many functions in the human body. Identify the function of the proteins given below?

	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	

BI 12.1.2.4 ENZYMES

- 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 37^0C.
- 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).

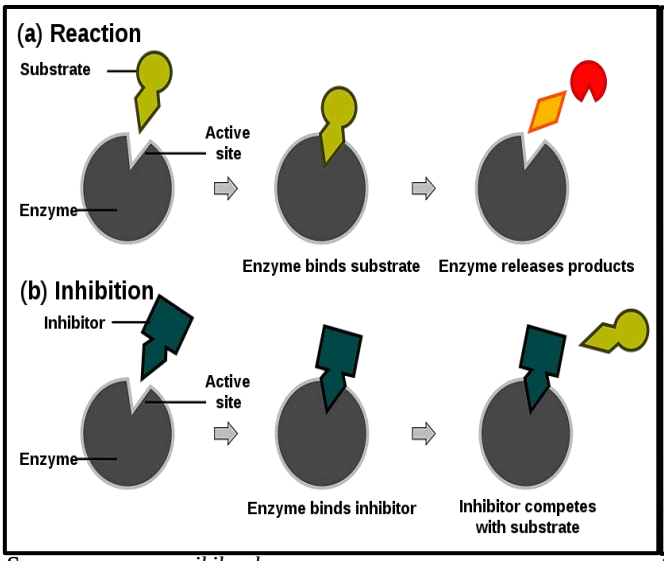
5. Inhibitors can prevent enzymes from acting on substrates

- 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.

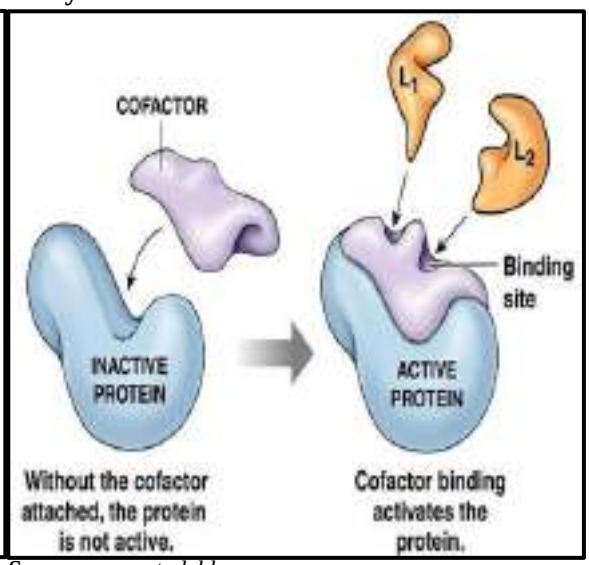
- Any substance that helps an enzyme to function is called a co-factor.
- Co-factors are usually vitamins or minerals.
- For example, vitamin B helps the enzymes that catalyses respiration. If a person does not get vitamin B in her diet, she will become paralysed. Eventually she will die because her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

Enzyme Action



Source: *www. en.wikibooks.org*

Enzyme Cofactors



Source: *www.studyblue.com*

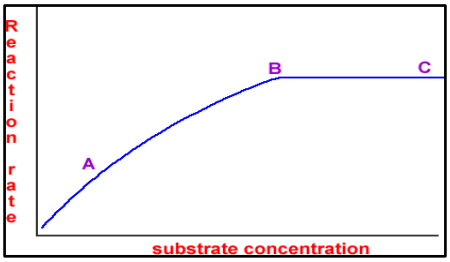
SELF TEST

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?

BI 12.1.2.5 BIOCHEMICAL REACTIONS

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.

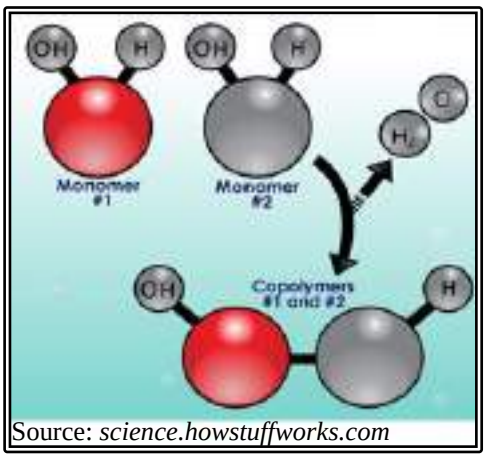
(6) **Respiration-** cells release energy by oxidising the bonds in the food molecules.

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

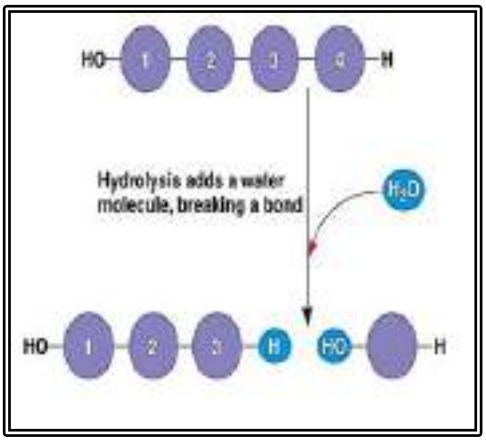
- Link small biochemical building blocks to form larger molecules.
- Also known as '**dehydration**' reaction because water molecule is lost when joining two small molecules.
- For example, when two amino acids join to form a peptide, water is the by-product of the reaction.
- Starch produced by plants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



Source: *science.howstuffworks.com*

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.



Source: *bio1151.nicerweb.com*

3. DNA Replication

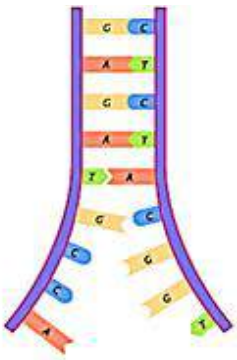
- ❖ DNA is a double strand of nucleic acids joined between the bases of the nucleotides.
- ❖ In order to pass the genetic information to the new cells (daughter cells), the old DNA strands make copies.
- ❖ The process of DNA replication is semi-**conservative** (semi = half; conservative = holding on)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

Steps in DNA Replication

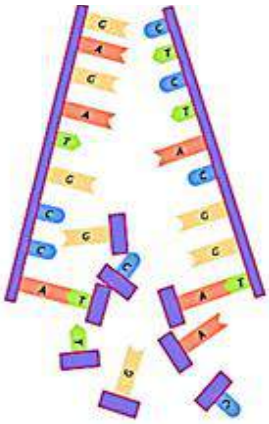
1) The parent DNA helix unwinds and separates into two separate strands.
2) Nucleotides are attracted to the complementary bases.
3) Complementary base pairing occurs.
4) The new strands join together using enzyme (DNA polymerase).
5) There are two identical DNA helix, each consisting of the one original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

1. A portion of DNA which will undergo replication.

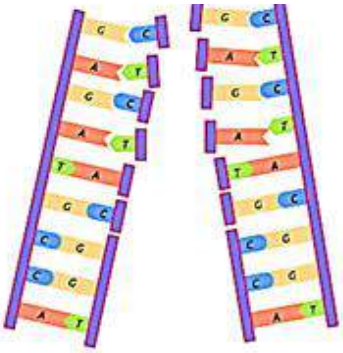
2. The 2 strands of DNA separate by breaking the hydrogen bonds between the bases.



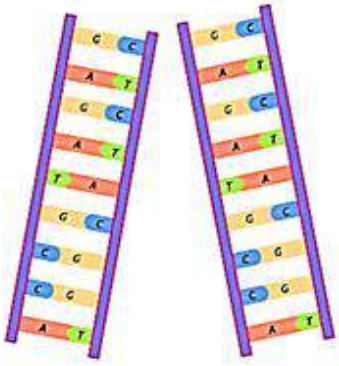
3. Free nucleotides attracted to their complementary bases.



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.

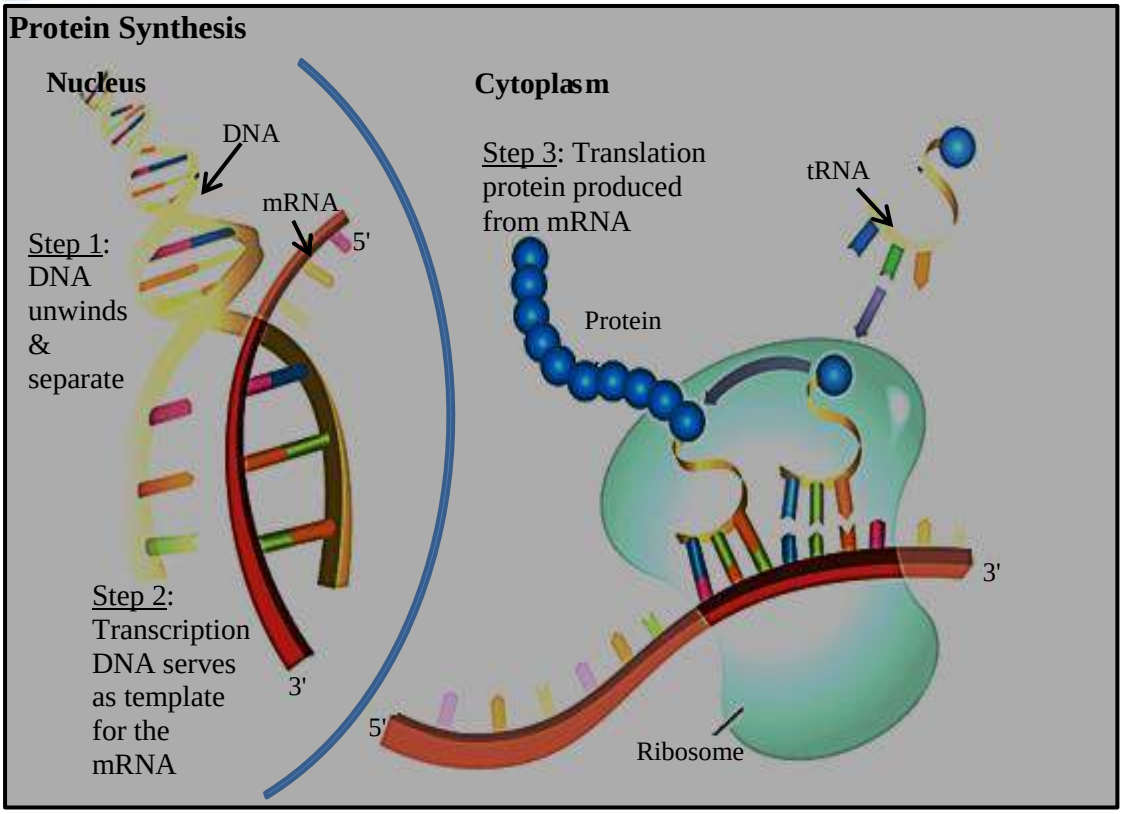
iii. Translation

- 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 m RNA 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.

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

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
   b. mRNA
   c. tRNA
   d. ATP
   e. NAD^+
   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 as 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.

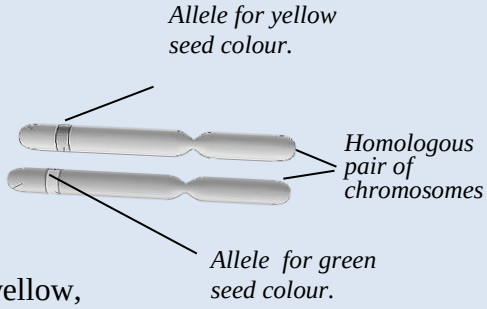
NB: *The genotype codes for the phenotype.*

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: **Y Y** x **y y** 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.

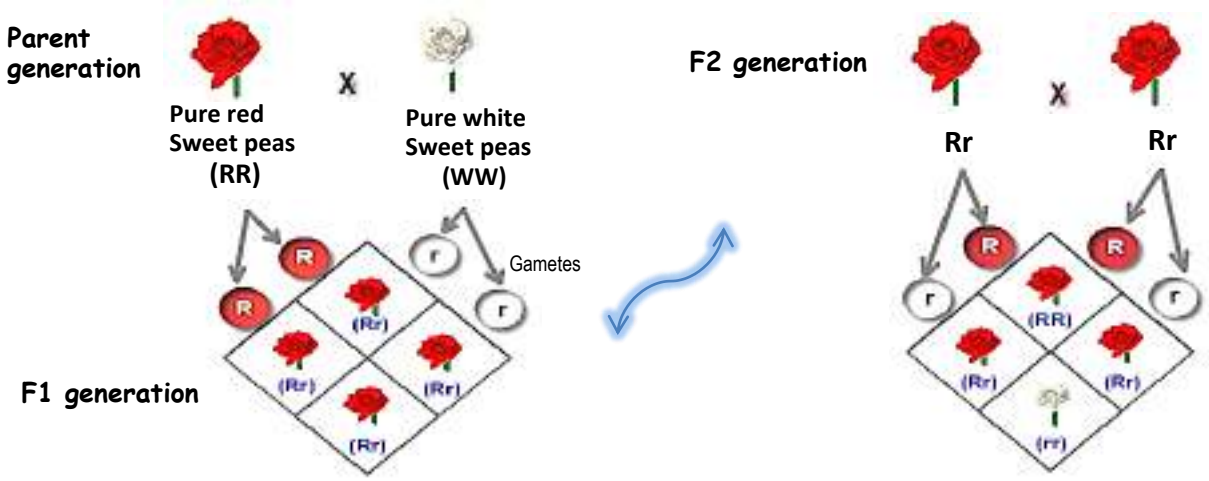
= the ratio is **3:1**

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.

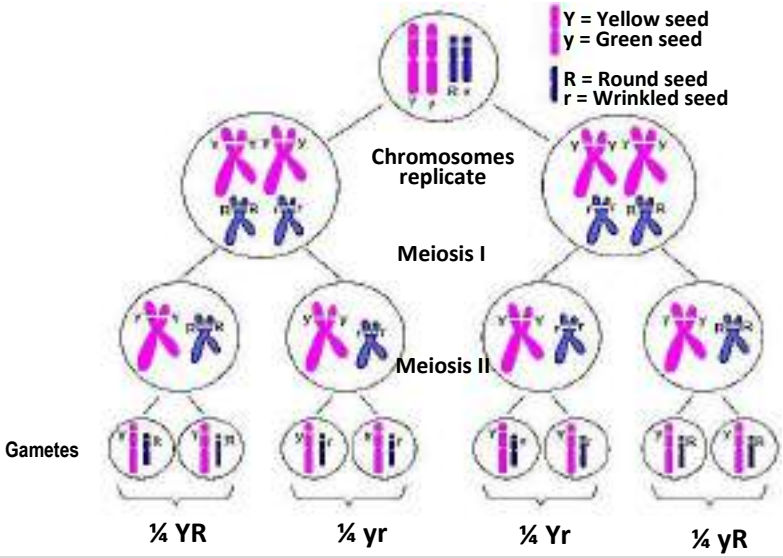
Law of Segregation (Mendel's 1st Law)

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.



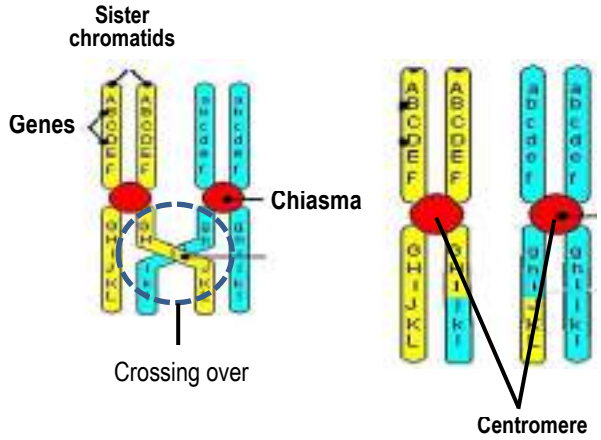
Law of Independent Assortment (Mendel's 2nd Law)

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 places 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

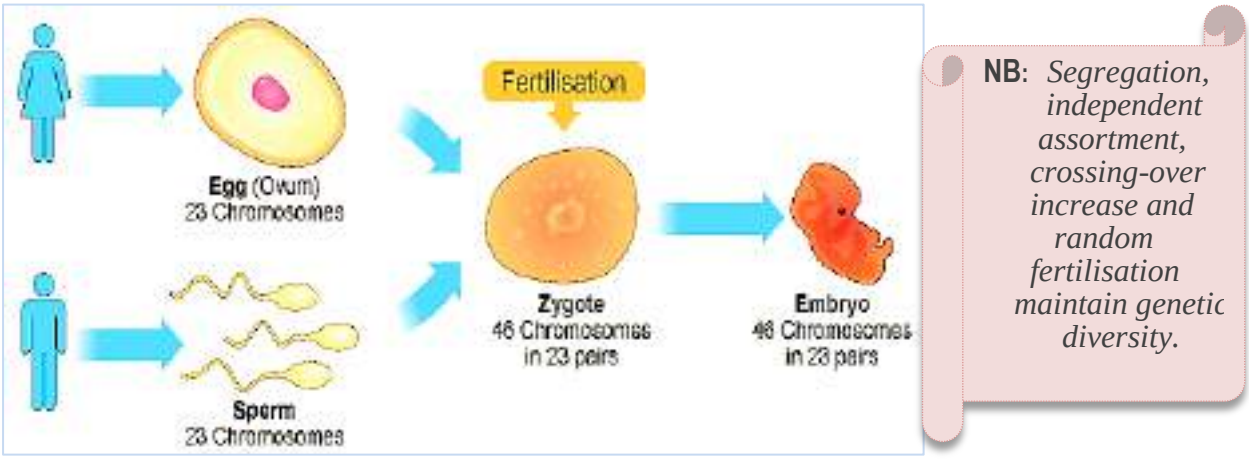
Genetic recombination is the genetic transmission by which the combinations of alleles observed at different loci in two parental individuals become shuffled in offspring individuals. During meiosis, homologous chromosomes (1 from each parent) pair along their lengths. The chromosomes cross over at points 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.



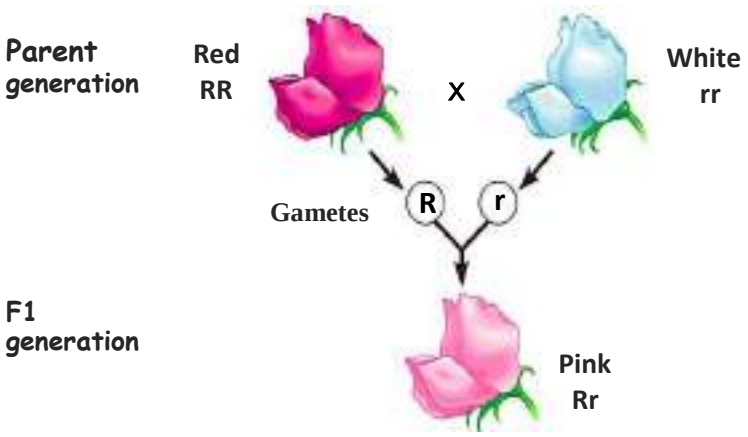
Source: *http://www.bbc.co.uk/staticarchive/*

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

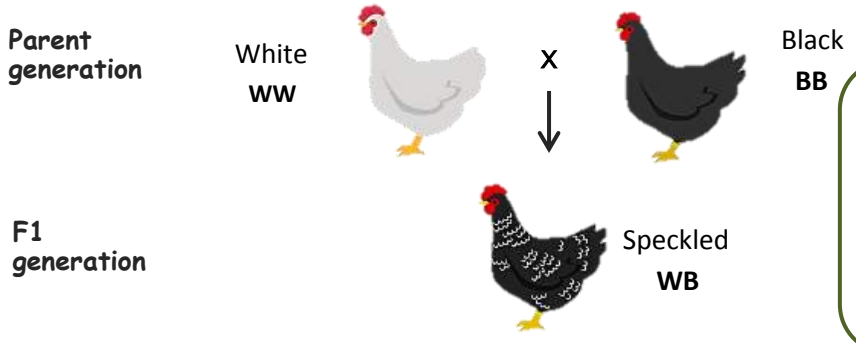
With incomplete dominance, a cross between organisms with two different phenotypes produces offspring with a ***third*** phenotype that is a '*blending of the parental traits'*.



- 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 n 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^AI^A or I^Ai	Type A blood
I^BI^B or I^Bi	Type B blood
I^AI^B	Type AB blood
ii	Type O blood

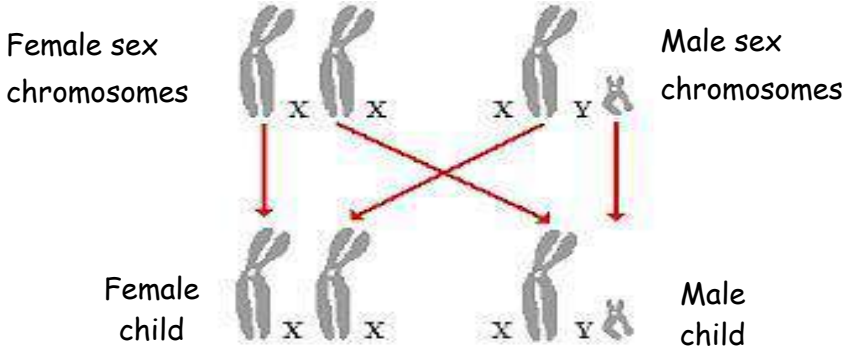
NB: *Each organism inherits only two alleles regardless of the number of alleles present for a trait.*

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-liked 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.

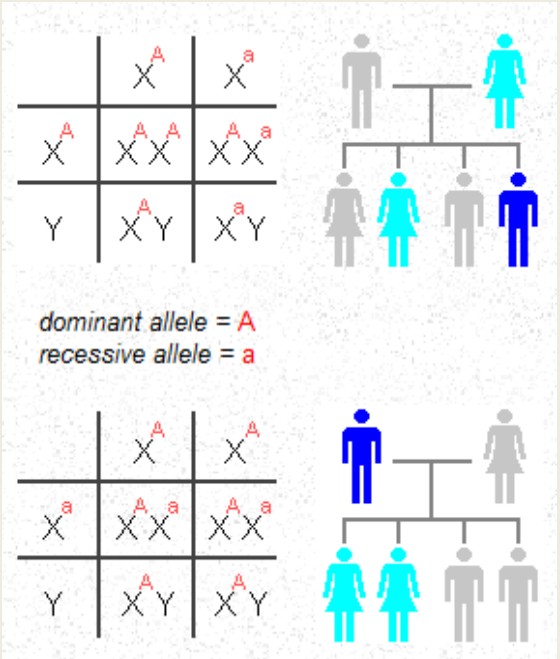
Note:

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:

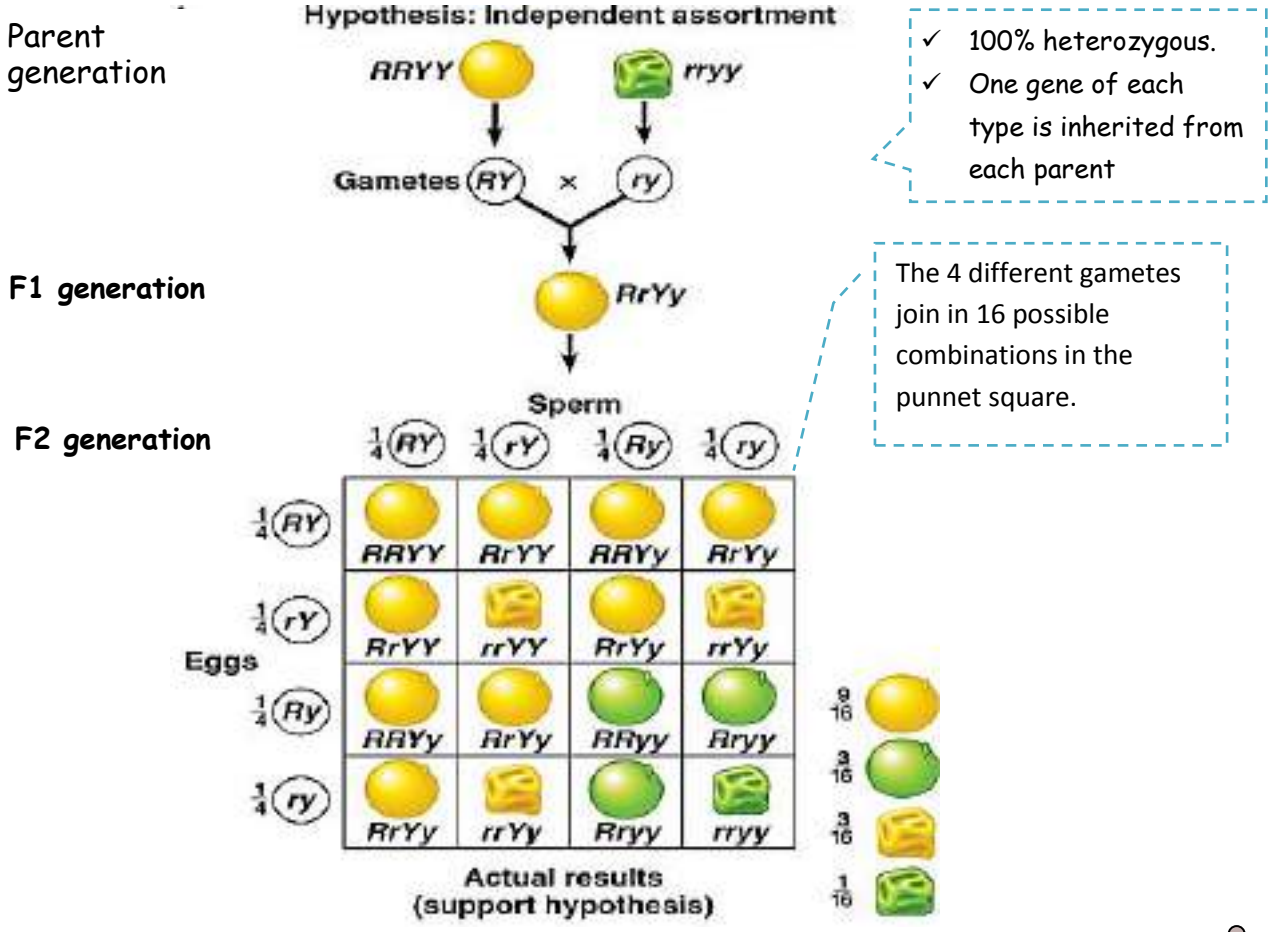
RR = homozygous dominant for smooth coat or shape
rr = homozygous recessive for smooth coat or shape or in other words (wrinkled seeds)
YY = homozygous dominant of yellow colour
yy = homozygous recessive for yellow coat colour or in other words (green seeds)

- 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 F2 generation is:

9:3:3:1

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

Source: *http://www.mpietrangelo.com/*

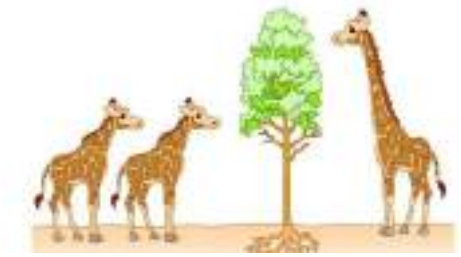
VARIABILITY

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.

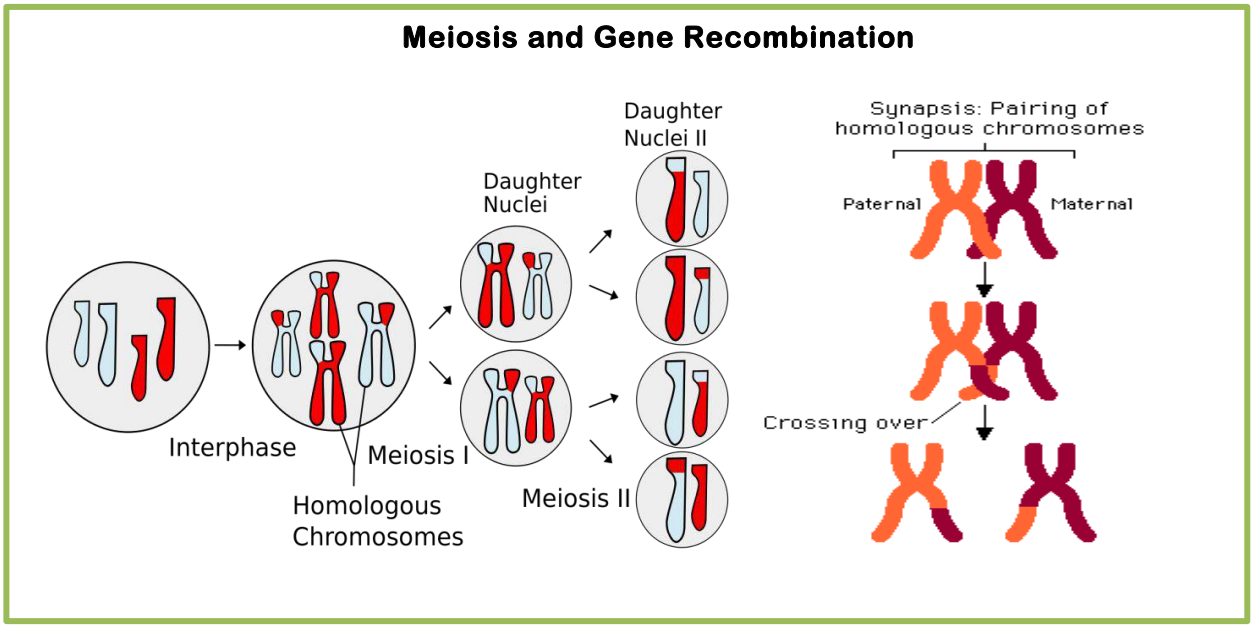
In meiosis I;

- 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.



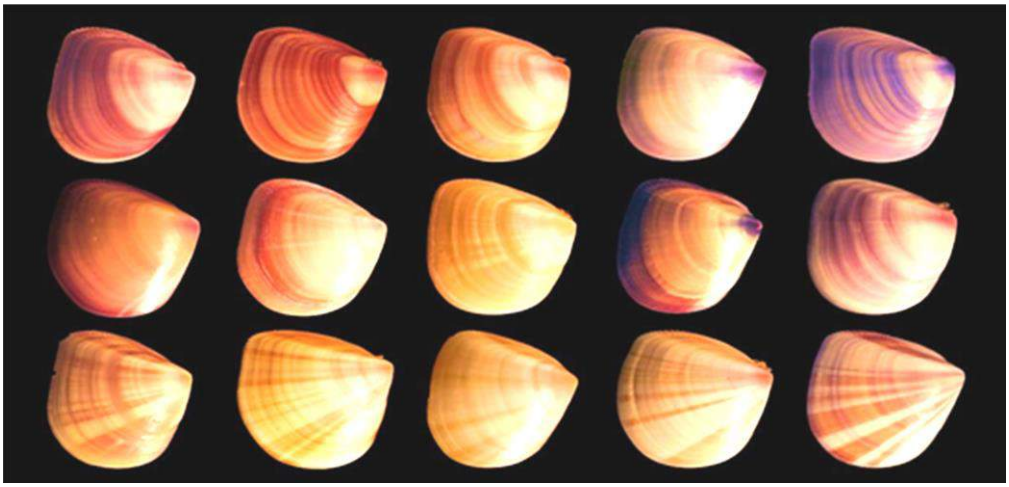
3. Mutation (genetic)

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* (coquna 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 (autosmal)
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.

EVOLUTION

The Theory of Evolution

Evolution is considered as the cornerstone of modern biology. It unites all the fields of biology under one theoretical umbrella. It is not a difficult concept, but very few people including majority of biologists understand it concisely. One common mistake legging with evolution is that species can be arranged on an evolutionary ladder from bacteria through 'lower' animals, to 'higher' animals and, finally, up to man.

What is Evolution?

- Evolution is a change in the gene pool of a population over time.
- A gene is a hereditary unit that can be passed on, unaltered for many generations.
- The gene pool is the set of all genes in a species or population.

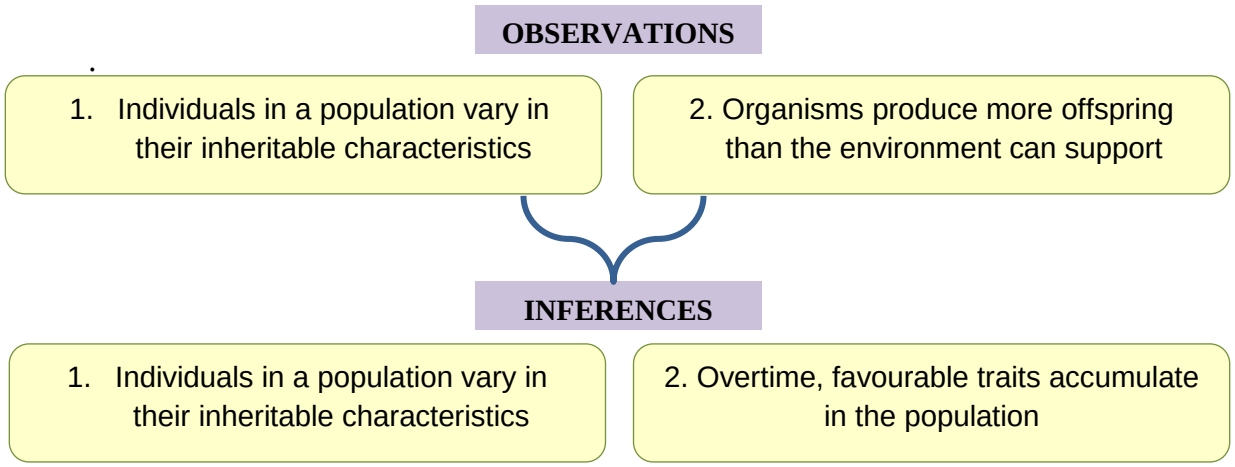
Source: *http://www.talkorigins.org/faqs/faq-intro-to-biology.html*

The theory of evolution is interlaced with the works of two famous scientist named **Charles Robert Darwin** and **Jean Baptiste de Lamarck**. However, their inference on how evolution occurred is based on conflicting ideas.

Darwin's Theory (Darwinism)

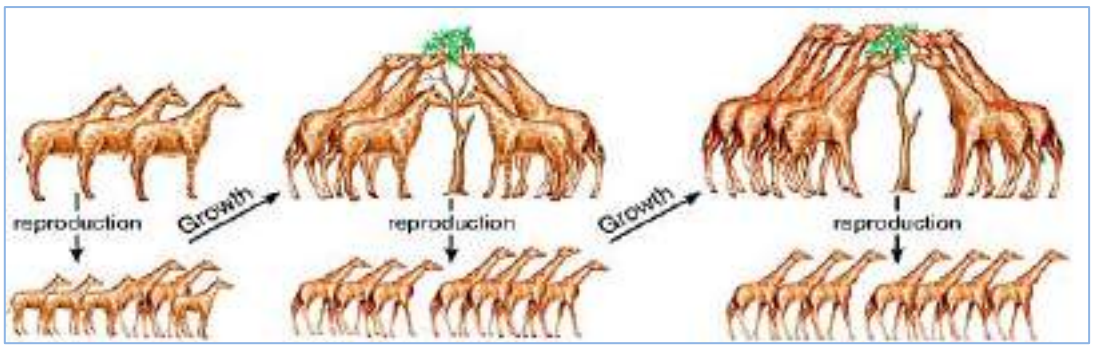
Darwin's book "On the Origin of Species" in 1859, first documented the theory of evolution by ***natural selection*** whereby organisms change over time as a result of changes in heritable physical or behavioural traits. Changes that allow an organism to better adapt to its environment will help it survive and have more offspring.

Darwin supported his theory with two sets of observations:



- Darwin's theory of natural selection is further discussed later.

Example



Some individuals born happen to have longer necks

Over many generations, longer-necked individuals are more successful, perhaps because they can feed on taller trees. These successful individuals have more offspring and pass the long-neck trait on to them.

Lamarck's Theory (Lamarkism)

Lamarck's theory proposed positive evolutionary changes that resulted from changing needs or changes to the environment.

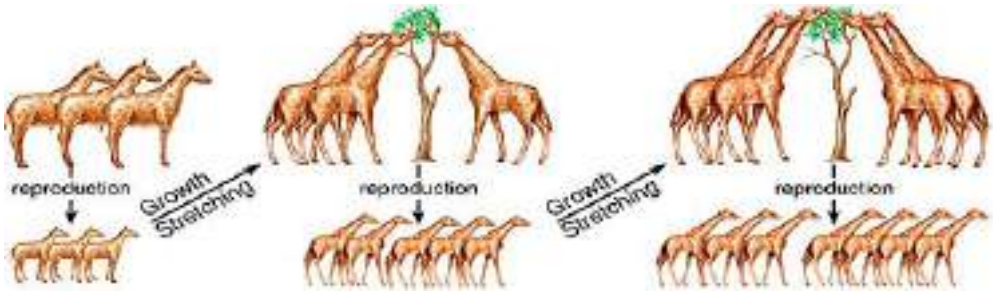
He based his theory on two principles.

PRINCIPLES

1. Use and disuse
2. Inheritance of acquired traits

- The law of 'use and disuse' explains why entire species lose functions and organs they do not need or use. In other words, they only develop characteristics that are useful.
- The human appendix, for example, is just the vestige of an organ which once was useful while the function of standing and moving with an upright posture helped our immediate forefathers survive and thrive.
- **Inheritance of acquired traits** is the aspect of Lamarckian evolution that has caused the most controversy over two centuries.
- Lamarck believed that tiny changes in an organism could be triggered by an environmental event.
- These tiny changes were passed on to subsequent generations, benefiting entire populations and creating new species.
- Lamarck felt that there was a pattern in nature imposed from outside; that animals were constantly striving to be better.
- He believed in the idea of continuous progress, that somehow nature had arranged things so that we kept on improving. (Source: *http://lamarcksevolution.com/evolution-an-introduction/*)

Example



Ancestor of giraffes with all long neck

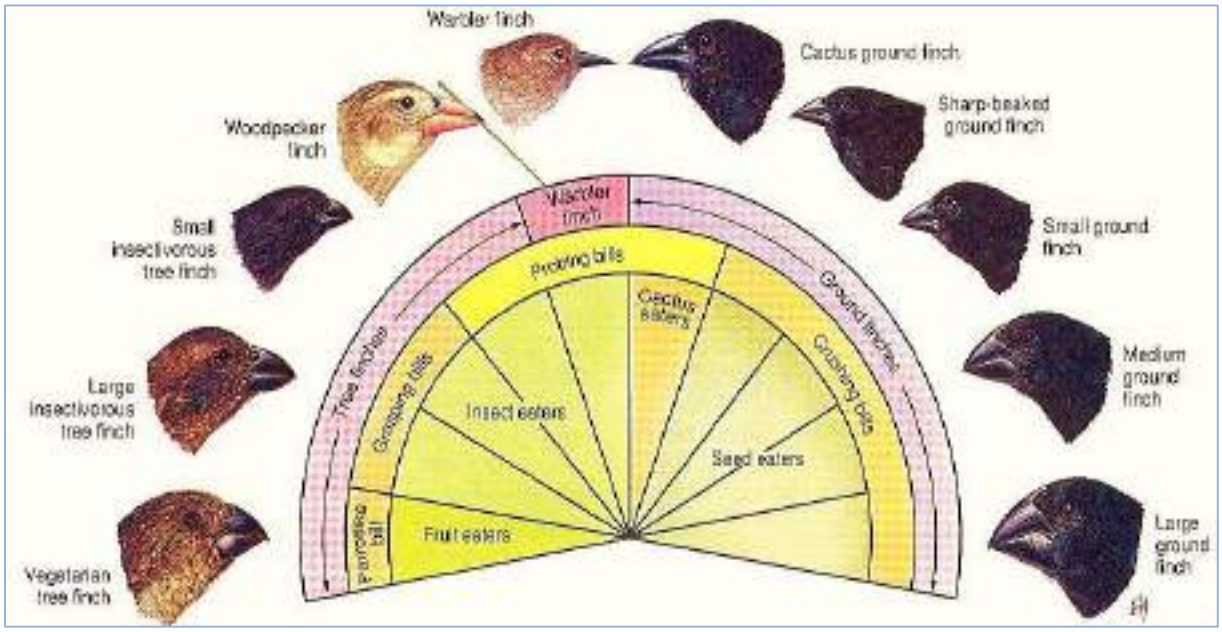
The giraffe ancestor lengthened its neck by stretching to reach tree leaves, then passed the change on to the offspring

Source: *http://www.zo.utexas.edu/*

Darwin's theory versus Lamarck's theory	
Darwin	**Lamarck**
– Theory of natural selection	– Theory of use and disuse
– Inheritance and variation	– Transmission of acquired traits
– Differential survival	– Increasing complexity
– Extinction	– No extinction

Adaptive Radiation

- Adaptive radiation is an evolutionary process which results in the diversification of a single ancestral lineage.
- Adaptive radiation takes place when members of a single species occupy a variety of niches with different environmental selection pressures.
- Members of a common species evolve into different morphological adaptations resulting in speciation.
- The process of adaptive radiation may be further enhanced by reproductive barriers such as habitat isolation.
- An excellent example of adaptive radiation are the Galapagos finches (shown below), also known as Darwin's finches.
- About 14 - 15 species of finches derived from a common ancestor, occupy individual adapted ecological niches due to the size and shape of their beaks in relation to the food they eat.
- Adaptive radiation is said to be possible only when the competition is absent or reduced.
- Thus competition plays a very important role in the evolutionary theory.



Source: *https://www.mun.ca/biology/scarr/Geospiza_beaks.jpg*

SPECIATION

To understand the concept of speciation one must first understand what *species* means.

A species;

- Is a group of living organisms comprising of similar characteristics and having the potential to exchange genes or interbreed to produce fertile offspring under natural conditions.
- Members of a species have a common gene pool.
- Members of a species can interbreed with the members of their own species only.
- Therefore, it can be said that a population of species is reproductively isolated from a population of another species.

Example:

Source: *http://images.tutorvista.com*

The 'happy face spiders' shown above are different in appearance but they have potential to interbreed. Therefore, they are considered as belonging to one common species of *Theridion Grallator*.

Speciation

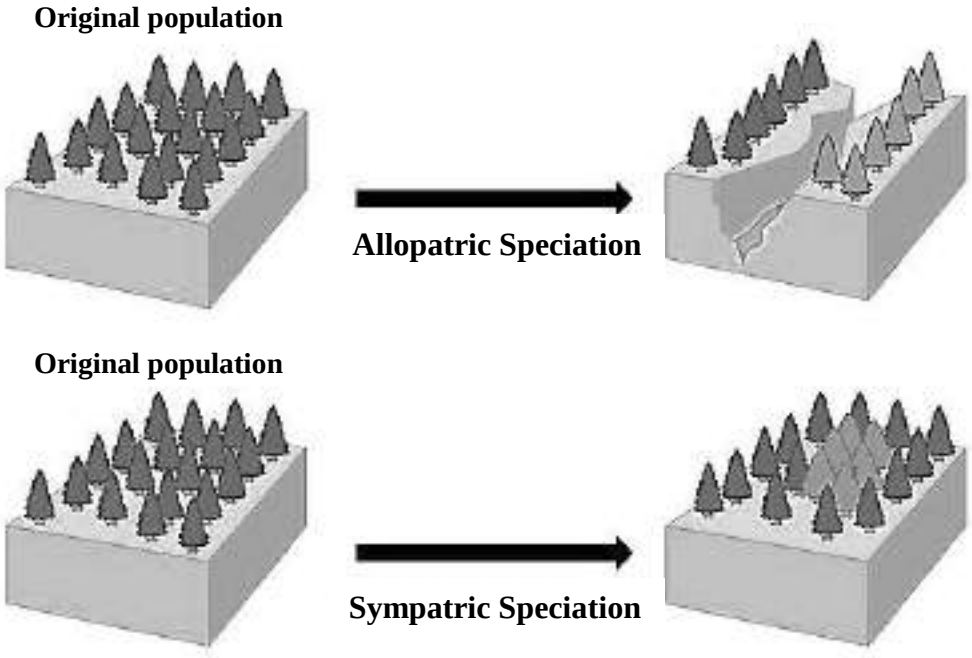
- Speciation is the evolutionary process that leads to the formation of new species.
- Species originate by the process of **speciation**.
- When members of a population **diverge**, they evolve in two or more different directions.
- They may become so different that they can no longer interbreed.
- At this point of divergence, they are separate into different species.
- Divergence to the point of speciation occurs under a number of circumstances.
- Geographic isolation is one of the major causes of speciation.

Speciation can occur in two major ways which is dependent on how gene flow is interrupted between populations of the existing species.

These two methods of speciation are:

1. **Allopatric Speciation** is where a population forms a new species due to a geographical barrier that has separated the initial original population into two separate populations which cannot interbreed. This is phenomenon is also known as **geographical isolation.**

2. **Sympatric Speciation** is where geographical isolation and thus reproductive barrier occurs in populations living within the same population. The reproductive barrier forms due to factors like polyploidy, habitat differentiation or sexual selection.



Evolution is a biological phenomenon common to all living things, even though it has led to their differences.

❖ The theory of evolution is supported by many pieces of evidence ranging from similarities at DNA level to similarities within the structure of the organisms.

Evidence to support the theory of evolution has come primarily from:

- ✓ fossil record
- ✓ comparative studies of structure and function
- ✓ studies of embryological development
- ✓ biochemical evolution

1. Fossil Record:

- Fossils are the preserved remains or traces of animals, plants, and other organisms from the past.
- Fossils provide important evidences for evolution by reflecting the difference in life forms during previous life on earth in comparison to today.
- Normally, only a portion of an organism is preserved as a fossil, such as body fossils (bones and exoskeletons), trace fossils (feaces and footprints), and chemofossils (biochemical signals).

Fossilised leaf on rock

Source: *http://www.geology.com*

Fossilised Fish on rock

Source: *http://www.pbslearningmedia.org*

These anatomical structures are classified as; **Analogous** and **Homologous** structures.

Analogous structures

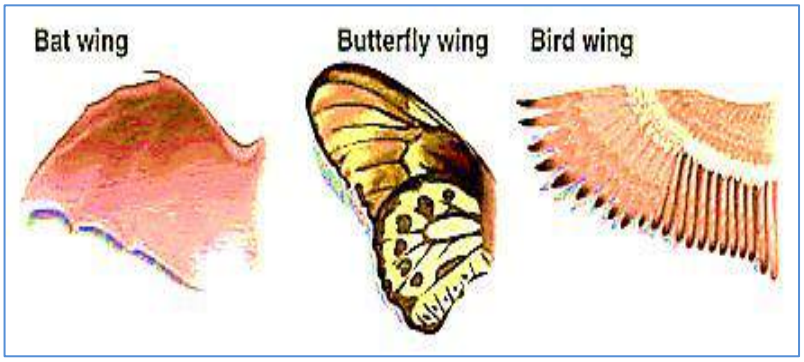
- **Analogous structures** are body structures that have evolved separately but serve the same function.
- They are not inherited from a common ancestor.
- Structures look similar and may have similar functions but they are a result of convergent evolution i.e. they are not closely related on the tree of life.

- **Convergent evolution** is when two unrelated species undergo several changes and adaptations to become more similar.

- This evolution occurs when two species living in similar climates and environments in different parts of the world have similar selection pressures and hence, tend to develop similar adaptations.

Example of Analogous Structures

- Bats, flying insects, and birds are all adapted to their niches in their environments by developing wings.
- Their wings are ***not indicative*** of a close evolutionary relationship.



Source: *https://kozmopolitaydinlar.files.wordpress.com/*

Other Examples

Several organisms have separately evolved similar body shape and structures which adapt them for swimming.

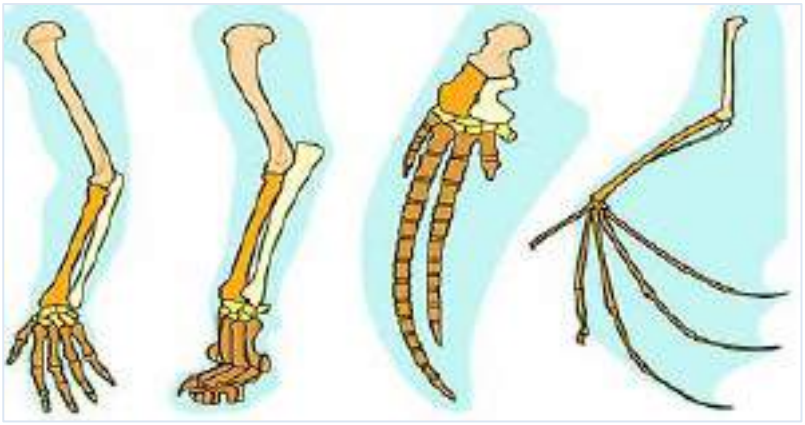
- Sharks inherited their streamlined body shape and fins from fish ancestors.
- Penguin's bird ancestors use wings to fly, but penguins, which evolved to fill a swimming and fishing niche, now use their wings like fins.
- Dolphins' ancestors used their limbs to walk around on land; today these mammals swim the seas with front legs that have evolved into a fin shape.
- Selection for fast swimming caused all three animals to evolve analogous structures.
- Selection pressures for escape and food gathering, for example, has caused wings to evolve at least three separate times, once in insects, once in birds and once in mammals (in bats).

Homologous Structures

Different species which share a common ancestry often have **homologous structures**

- Structures which have the same form, inherited from a common ancestor, but which have since evolved to serve different functions.
- For example, all vertebrates have very similar bone structure in their two front limbs.
- Compare the bones in a human arm, a bird wing and a whale fin.
- The number and positions of the bones are very similar, yet the length and thickness of the bones have evolved to serve different functions whether using them as tools for flying or swimming.

Example of Homologous Structures

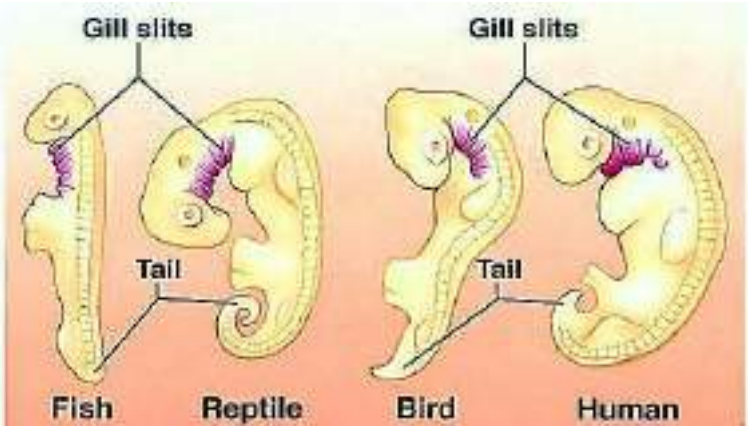


Human Cat Whale Bat

Source: *http://www.bio.miami.edu/dana/pix/homologous.jpg*

3. Embryology

- Comparison of the early stages of development in the different animal species reveals additional homologies that are not visible for adult organisms.
- For example, at some point in their development, all vertebrate embryos have a tail located posterior to the anus as well as the structures called pharyngeal (throat) pouches.
- These homologous throat pouches ultimately develop into structures with very different functions, such as gills in fishes and parts of the ears and throat in humans and other mammals.



Source: *http://www.mhhe.com/*

4. Vestigial Structures

- **Vestigial structures** are body parts which now serve little or no function.
- These structures are homologous to functional organs of their evolutionary relatives.
- Vestigial structures are basically those body parts which an organism no longer needs in its niche.

Example:

- Snakes have tiny, useless hind limb bones left from their four-legged lizard ancestors.
- Humans have an unused appendix, which maybe the vestige of a *'house'* for a cellulose-digesting bacterium inherited from our leaf eating monkey ancestors.
- Many cave-dwelling organisms have eyes which, after generations of living in complete darkness, have lost its function for sight.
- Wings of flightless birds like the Kiwi and Penguin which are not used for flying.

Biochemistry (DNA)

- Cytochrome c is a haemoprotein found in all aerobic organisms and which plays a vital role in cellular organisation in both plants and animals.
- The amino acid sequence in cytochrome c is the same in humans and chimpanzees (apes that we are most closely related to humans).
- The number of differences in the amino acid sequence becomes greater moving away to more and more distantly related species.
- A similarity in cytochrome c denotes a similarity in DNA strands.
- The fact that human DNA is very similar to ape DNA is a piece of biochemical evidence in the favour of evolution.
- If plant and animal species had been created separately then this progressive differentiation in DNA would not be seen.
- Another piece of biochemical evidence in favour of evolution is the following:
    - Each amino acid in any organism is coded for by the various sequences of the same triplet of DNA bases.
    - Complementary codons on the mRNA select the amino acids, and the sequence of codons determines the sequence of amino acids and, hence, the protein that is produced.
    - The connection between codons and amino acids that are selected to produce a protein is called the genetic code.
    - The genetic code is common to all living things.
    - This common genetic code for the selection of amino acids is another piece of evidence in favour of the evolution.

Natural selection *(survival of the fittest)*

- Charles Darwin, in his theory of natural selection, suggested that "***survival of the fittest***" was the basis for evolution (the modification of living things with time).
- The limited resources available in an environment give rise to competition whereby organisms of the same or different species struggle to survive.
- In the competition for food, space, and mates that occurs, the less well-adapted individuals must die or fail to reproduce, and those who are better adapted do survive and reproduce.
- Selection pressures that drive towards evolution are divided into two factors:

i. **Biotic factors** include competition, predation, parasitism and diseases.

ii. **Abiotic factors** include natural disasters such as, flooding, draught, cyclones, tsunami etc.

- Darwin also proposed a theory of sexual selection, in which females chose the most attractive males as their mates; outstanding males thus helped generate more young than mediocre males.
- Other forms of selection pressures like spread of diseases and parasitism also lead to evolution where the weaker species got wiped out and those that developed resistance to diseases, survived and reproduced more and more offspring with genes that favoured survival.

Examples of evolution by Natural Selection

1. **Peppered Moth**

– Peppered moths in England have two forms, one speckled light grey and the other dark grey.
– Once, nearly all the moths were speckled and almost none were dark.
– During the day, peppered moths rest on tree trunks. Before the industrial revolution, light-grey speckled lichens coated the tree trunks in England.
– The speckled moths were well camouflaged from predatory birds when resting on these trunks.

– The dark moths stood out. Then, in the 1850's, pollution from factories began to kill the lichens and blacken the trunks changing the selection forces on moth colour.
– By the end of the 1800's, biologist could hardly find any light speckled moths.
– The vast majority of the moth population was dark. Birds, which could spot the light moths easily on dark trunks, probably picked them off the trees.

2. **Antibiotic Resistance**
Widespread use of antibiotics selects for the drug-resistant strains of pathogenic bacteria. Some new strains of tuberculosis, a previously curable disease, are not responding to the most powerful antibiotics that doctors have.

3. **Pesticide Resistance:**
Pesticide (or insecticide) application may kill most of the pests on a crop. However, a few insects will probably survive due to some feature that makes them more resistant. If these resistances are genetic, they will pass it on to their offspring. Then many insects in the next generation will survive the next spraying.

SELF TEST

Inheritance

1. Which one of Mendel's laws relates to the;

   i) Inheritance of allele as a single character?
   ii) Inheritance of two characters in a dihybrid cross?

2. An organism with the genotype BbDD is mated to one other with the genotype BBDd. Assuming independent assortment of these two genes, write the genotypes of all possible offspring from this cross and use the rules of probability to calculate the chance of each genotype occurring?

3. If a man with blood type AB marries a woman with blood type O, what blood types would be expected in their children?

4. In cats, the dominant sex-linked gene (**C**) results in lack of pigmentation (white fur) and cross-eyed condition. Its recessive allele (**c**) produces coloured fur and normal eyes. If a normal eyed female with coloured fur is mated with a white fur and cross-eyed male; what phenotypic ratio of offspring should occur in the **F1** and **F2** generation?

5. During early embryonic development of female carriers for colour blindness, the normal allele is inactivated by chance in about half the cells. Why then, aren't 50% of the female carriers colour-blind?

Variability

1. Define variability and explain how it is related and/ important for evolution.

2. Explain how a mutation maybe beneficial.

3. List the four sources of genetic variation.

4. How would you identify Down Syndrome, Turner's syndrome and Klinefelter's syndrome from a karyotype?

Evolution

1. State the theory of evolution.
2. Before Darwin proposed his theory of evolution by natural selection, a naturalist named Lamarck suggested a very different idea of evolution. Compare the two theories and provide justification for which of the two theories is acceptable.
3. Explain how competition for limited resources creates natural selection pressure on organisms.
4. What was the main selection pressure which created the colour change in peppered moths over generations?
5. Give evidence which suggests that humans are related to apes?
6. What selection pressures probably caused the evolution of different beak shapes in the Galapagos finches?
7. Through evolutionary history, animals capable of increasingly greater speeds have evolved. Explain why speed may have been selected for.
8. What is a fossil? How do fossils provide evidence of evolutionary change?
9. What is the difference between homologous structures and analogous structures? Give an example of each.

STRAND 1

YEAR 12

SUB-STRAND 1.4

COMPARATIVE FORM AND FUNCTION IN PLANTS AND ANIMALS

SUB-STRAND 1.4: COMPARATIVE FORM AND FUNCTION IN PLANTS AND ANIMALS

ACHIEVEMENT INDICATORS

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

- ✓ Study the storage and utilization of food in plants.
- ✓ Compare and contrast the digestive systems of selected invertebrate and vertebrate animals to show increasing complexity.
- ✓ Discuss the process of digestion in selected organisms.
- ✓ Compare and contrast the gas exchange systems of selected organisms to show increasing complexity.
- ✓ Study the gas exchange system of selected aquatic and terrestrial organisms to their mode of life.
- ✓ Name and describe the different methods of transport in plants and animals.
- ✓ Recognise the increasing complexity of the vertebrate heart.
- ✓ Compare and contrast the excretory mechanisms of selected organisms to show increasing complexity.
- ✓ Compare and contrast osmoregulation in selected organisms to their mode of life.
- ✓ Evaluate the different forms of protection, support and movement in selected organisms.
- ✓ Compare and contrast support and movement in selected invertebrates and vertebrates.
- ✓ Explain the sensory system in plants and explain how its co-ordination helps the plants to survive.
- ✓ Explain the sensory system and relate the efficiency of co-ordination to symmetry type in animals.
- ✓ Explain the need for reproduction.
- ✓ Differentiate between the various asexual methods of reproduction in animals.
- ✓ Differentiate between internal and external fertilization.
- ✓ Evaluate the factors contributing to the reproductive success in plants and animals, using specific native examples.

BI 12.1.4.1 NUTRITION

- Nutrition is the process of providing food to the body cells for health and development (growth).
- Plants, bacteria, fungi, protists and animals, all need a constant supply of energy to survive and reproduce.
- They get their energy from food.
- Every organism has a nutrition method adapted to its lifestyle.

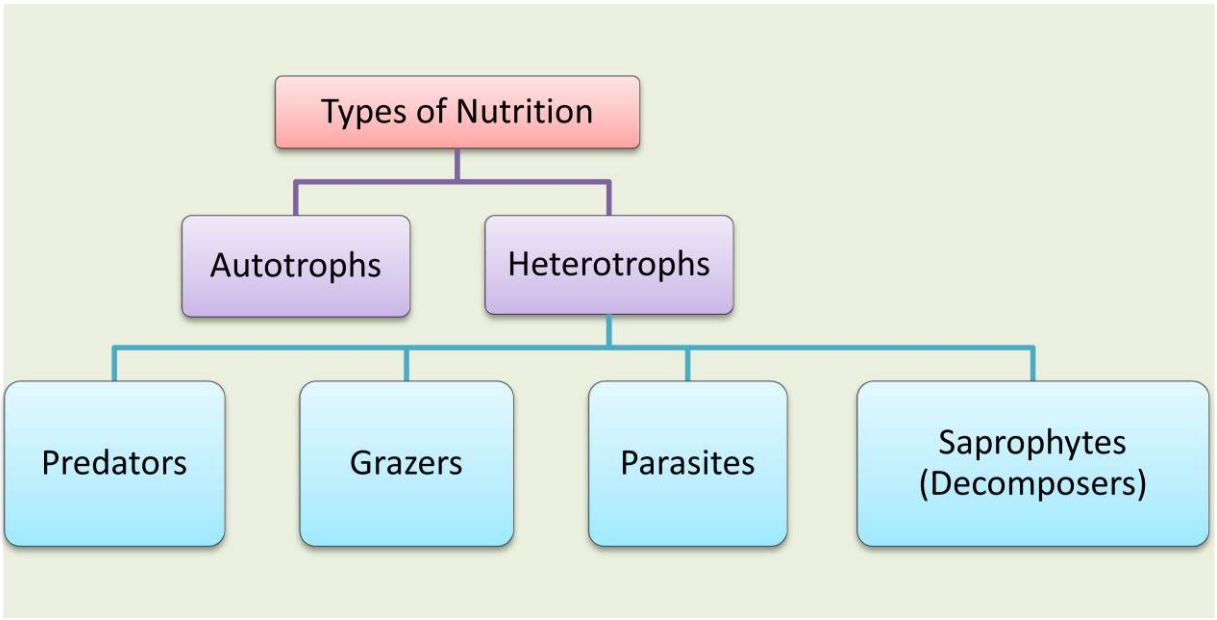
Nutrition methods

- Plants and animals have different processes of obtaining food (energy).
- Plants and some bacteria have chlorophyll (green pigment) to help them make their own food.
- Animals, fungi and other bacteria depend on plants and other organisms for food.

There are two main modes of nutrition: **Autotrophic** and **Heterotrophic.**

Autotrophic nutrition is the process by which green plants manufacture their own food by converting solar energy (sunlight) into chemical energy (food).

Heterotrophic nutrition is the process whereby organisms that cannot make their own food obtain their food (energy) either directly or indirectly from plants or other organisms.



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Autotrophs (‘*auto’ means self* **)**; organisms that are capable of making their own food using the solar energy (sunlight) into chemical energy (food) . E.g. plants, some bacteria and some protists.

Heterotrophs (‘*hetero’ means different or other*) organisms that cannot make their own food and depend on plants or animals food.
E.g. animals, fungi, most bacteria and protists.

Predators: organisms that prey (hunt and kill) on other organisms. E.g. sharks prey on big or small fish, toads prey on lizards and insects, cats prey on mouse and birds, mynah bird preys on worms.

Grazers: organisms that feed on an entire population, often without killing them. E.g. cows, goats, green sea turtle, filter feeders (kai and coral), herbivorous insects and some fish.

Parasites: organisms that live and feed on or in an organism of a different species and cause harm to their host. E.g. bacteria, fungi, fleas, ticks, nits, lice, tapeworms, protists etc.

Saprophytes (decomposers): organisms which get their energy by feeding on dead organic matter causing it to decay. E.g. fungi, bacteria, maggots, insects, grubs, snails, slugs, beetles, millipedes, ants etc.

Microphages: animals (mostly aquatic) that feed on very small particles suspended in water like phytoplankton and tiny organic fragments.

Fluid feeders: Are organisms that feed on liquid food from plants and animals. There are two groups of fluid feeders;

- **Wallowers** - are organisms that literally wallow (roll about relaxed in water or mud) in their foods. E.g. a gut parasite such as tapeworm.
- **Suckers** – are insects and spiders with mouthparts in the form of a proboscis for piercing and sucking. E.g. Housefly, mosquitoes.

Filter feeders: Include aquatic organisms like sponges, sea squirts, bivalve mollusc and mosquitoes on land. They employ filtering systems to collect, sort and concentrate the particles from water.

Gulpers: Organisms that gulp down their food whole and swallow without chewing their food first. E.g. snakes, *hydra,* sea anemone, frogs and fish-eating birds.

Masticators: Organisms that bite, tear or chew their food into smaller pieces before swallowing. Herbivorous animals such as a cow is a very good example of a masticator which chews it food for long.

- **Heterotrophs depend on the autotrophs for food.**
- Food is required by the organ system of the body to keep the organism alive and to provide ***energy*** for the various bodily processes and activities carried out by the organism.
- Different types of organisms are adapted differently to their environment and way of life.
- **Active and large organisms** require plenty of energy and so need lots of food quickly. E.g. humans, cows, dogs, cats etc.
- **Sessile organisms** require only small amounts of energy and so do not need much food.

Nutrition in Plants

Food manufacture

The food manufacturing (making) process in plants is called Photosynthesis. Photosynthesis has been widely discussed earlier hence, here will summarise the entire process.

Ingredients used:

- Plants need several inorganic materials in order to make food.

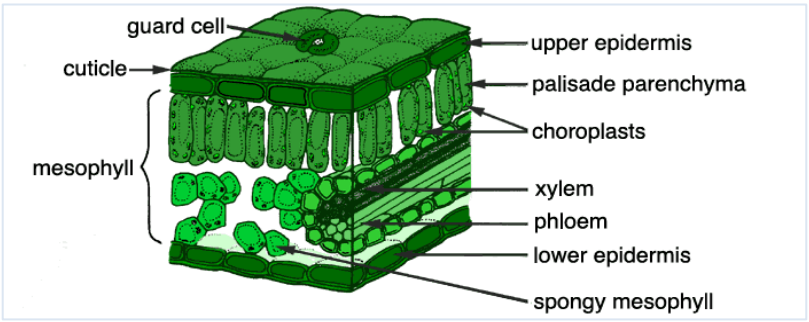
Following are the raw materials (ingredients) required for photosynthesis and the adaptations of plants for obtaining these materials.

Sunlight for energy	Adaptation
	• Pigments in the thylakoid membranes of the chloroplast absorb light (solar energy) from the sun. • Leaves are broad for maximum surface area for absorption of light. • Leaves are small to allow light to filter to the leaves on the lower branches. • Palisade layer, with the highest density of chloroplasts in its cells, is close to the top surface of the leaf in order to absorb more sunlight. • Irregular-shaped cells in spongy tissues enhance scattering of light, increasing the path length of light travelling through a leaf, thus increasing the probability of absorption. Path lengthening is important for the weakly absorbed wavelengths of light.
Carbon dioxide	
	• Carbon dioxide (for carbon and oxygen atoms) • Stomata on the bottom surface of the leaf are open to allow for diffusion of CO_2 from the air into the leaf. • The spongy mesophyll leaf has plenty of air spaces so the gas can diffuse more easily to the palisade layer. • Leaves are usually very thin to allow faster diffusion.

Water	Adaptation

	• Water (for electrons, hydrogen ions, co-enzymes and minerals)
	  • Root hair increases the root surface area for absorption.
	  • The network of veins in the leaves helps transport water and carbohydrates.
	  • Roots show geotropism and hydrotropism.

Cross-section of a Leaf



Source: *https://sciencevogel.wikispaces.com*

Leaf Structure	Adaptation for photosynthesis
Cuticle	– Prevents loss of water from leaves
Epidermis	– Transparent protective layer. – Protects leaf without inhibiting photosynthesis.
Palisade layer	– Palisade cells are filled with chloroplasts to absorb maximum light for photosynthesis. – Palisade cells are long and thin so light has to pass through as many chloroplast as possible.
Mesophyll layer	– Has plenty of air spaces that increase the surface area inside the leaf to maximize.
Stoma	– Allow exchange of CO_2 and O_2
Guard Cells	– Allow the stoma to open and close to regulate loss of water from the leaves
Xylem	– Conducts water in plants
Phloem	– Conducts food in plants

Use of Ingredients

- Plants use light, carbon dioxide and water as the ingredients for making food by the process of photosynthesis.
- Oxygen is produced as a by-product of photosynthesis.

Carbon dioxide + Water + ATP (energy) → Glucose + Oxygen

CO_2 + H_2O + ATP (energy) → $C_6H_{12}O_6$ + O_2

Food Storage by Plants

- Plants store most of the food they make until they need for growth or reproduction.
- Phloem carries food from the leaves to cortex cells in the stems and roots.
- Food is stored as starch or glucose in the cortex cells.
- Consumers eat plants to get energy from their stored food.
- Except for flower nectar and fruits, plants make all food for their own use.

Food Usage by Plants

- When a plant needs to use some of its stored food, it hydrolyses starch into molecules small enough to pass through cell membranes.
- This process of food hydrolyses is called **respiration**.
- Respiration in plants is carried out in the mitochondria just like in other organisms.
- The phloem then carries the food molecules to the cells that need energy.

Glucose + Oxygen → ATP (energy) + Carbon dioxide + Water

$C_6H_{12}O_6$ + O_2 → ATP (energy) + CO_2 + H_2O

Mineral needs in Plants

In addition sunlight, CO_2 and water, plants also need specific minerals:

- ❖ Minerals absorbed by plants have to be first dissolved in water, in which minerals form ions.
- ❖ Charged ions cannot diffuse through the cell membrane due to mineral concentration often being higher inside a plant than outside. Therefore, plants actively transport minerals into their roots.

Mineral	Function/ role in Plants	When deficient and/ excess in Plants
Nitrogen	– Taken up by plants as NO_3^- and NH_4^+ – Used in larger quantities than any other mineral nutrient. – Component of proteins, nucleic acids, cofactors. – Part of chlorophyll molecule.	– Most frequently deficient for normal growth of non-legumes. – Plants become stunted (become yellow) on the older leaves. – Nitrogen is mobile in the plant so new leaves may remain green. – Excess nitrogen may delay maturity. – Cause excess growth and little fruiting in melons and tomatoes.
Potassium	– Taken up by plants as K^+ – Especially important in water/solute balance; involved in plant enzyme action. – It is a catalyst in many reactions; carbohydrate, starch and nitrogen metabolism. – Activates enzymes involved in photosynthesis, protein and carbohydrate metabolism. – Adjusts stomatal movement and water relations. – Helps disease resistance. – Increases quality of fruits and vegetables.	– Tips and margins of leaves turn brown. – Potassium is mobile so this occurs first on lower leaves. – Weakening of straw in grain crops (lodging). – Important in preventing non-protein nitrogen from accumulating in plants.
Phosphorous	– Taken up by plants as $H_2PO_4^-$ and $H_2PO_4^{2-}$ – Part of the protein molecule (phospholipids). – Necessary for transfer of energy during metabolic processes (ATP). – Speeds up maturity, promotes good root development, improves drought and cold tolerance, improves seedling vigour – Important in seed and fruit formation.	– Overall reduction in growth, causes stunting. — Dark green colour - purple cast in corn on lower leaves first because phosphorous is mobile. — Delay in maturity. – Failure of seed to form

Calcium	– Taken up by plants as Ca^{2+}. – Important in cell walls and in forming the spindle during cell division. – Calcium pectate gives strength to cell walls. – Needed for peg development in peanuts. – Plant root and tip elongation.	– When calcium is immobile, new growth is affected. – Failure of terminal buds to develop – Symptoms are not usually seen under field conditions because other problems caused by acidity of soil will generally become limiting factors. – Liming prevents Calcium deficiency from occurring.
Magnesium	– Taken up by plants as Mg^{2+} – Component of chlorophyll; involved in plant enzyme action. – Related to phosphorus metabolism. – Large quantities found in seed.	– Mg is mobile so symptoms occur first in old leaves – Causes interveinal chlorosis (whitish or yellowish striping effect on grasses).
Sulfur	– Taken up by plants as SO_4^{2-}. – Constituent of 3 of the 21 amino acids which form protein cysteine and methionine. – Present in the organic compounds that give the characteristic odours of onion, garlic, and mustard.	– Similar to N deficiency symptoms. – It is less mobile than nitrogen so deficiency may be more apparent on younger leaves.
Manganese	– Taken up by plants as Mn^{2+} and Mn^{3+}. – Can be absorbed through the leaves – Required in small quantities - large amounts are toxic (acid soils). – Activation of enzyme systems. – Chlorophyll synthesis.	– Mn becomes immobile upper leaves develop yellow streaks.
Iron	– Taken up by plants as Fe^{2+} or Fe^{3+}. – Acts as a catalyst in the production of chlorophyll.	– Occur on high pH soils or certain plants. – Immobile so deficiency symptoms occur on young leaves. – Inter-veinal chlorosis may turn leaves completely white.
Copper	– Taken up by plants as Cu^{2+} (can be absorbed through leaves) – Very toxic if too much applied. – Copper is a catalyst in chlorophyll formation.	– Immobile so upper leaves affected; youngest leaves are yellow and stunted – Vegetables - plants wilt and develop a bluish green cast.
Adopted from: *http://broome.soil.ncsu.edu/ssc051/Lec5.htm*		

DIGESTION

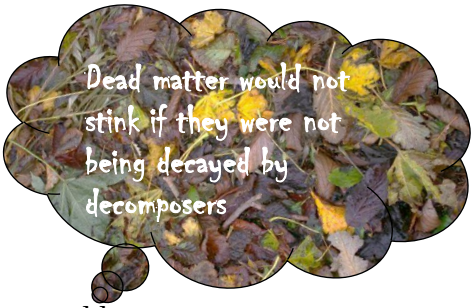
Digestion by biological means involves both mechanical and chemical processes to break up food into smaller or simpler constituent parts that can be absorbed by the body.

- Different organisms have different methods to digest food.
- The two common modes of digestion are **external digestion** and **internal digestion**.

- **External digestion** is where food is digested from the outside through secreting enzymes that degrade food material and then absorbed through diffusion.

Source: *http://bioweb.uwlax.edu/*

- Cnidarians as well as some bacteria and parasites also employ external digestion for obtaining nutrients.
- But most bacteria and fungi are decomposers, or saprophytes. They secrete digestive enzymes onto dead matter and wait for the enzymes to decompose the food which is then absorbed into their cells using active transport.
- External digestion is not suitable for mobile organisms as it requires the organisms to stay with food until it has completed digestion and absorption.
- Whilst, most bacteria and fungi species are not motile, external digestion saves them the energy expense of taking in large molecules and having digestive organs.



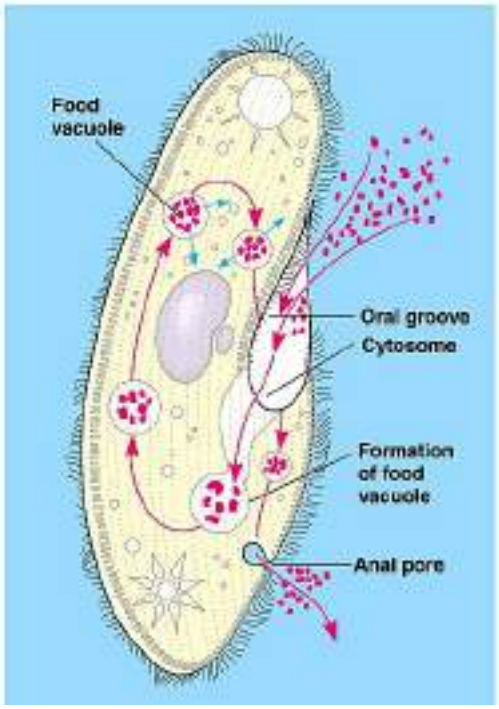
Importance of Decomposers

- Without decomposers, the world would soon be buried in dead leaves, animal corpses (dead body) and faeces.
- Plants would run out of minerals and without minerals, plants would not photosynthesize and the living world would suffocate and starve as it runs out of oxygen and food.
- Saprophytic bacteria and fungi quietly go about their business of acquiring energy from dead organic matter, and keep the world community alive by breaking down dead organisms and releasing minerals.

Nutrition in Protists

- Protists are unicellular organisms that are usually classified as a separate kingdom.
- Some protists function as one-celled plants; they photosynthesize.
- Others obtain food from their environment, like one-celled animals.
- A common example of protists is the Paramecium.
- Paramecium is a genus of protists that lives in fresh water.
- Their mode of locomotion is by beating of the cilia that cover their cell membranes.
- They feed on bacteria that float in water. Cytosome

How does a Paramecium feed?



Paramecium feeding steps:

1. A paramecium is a minute particle feeder which uses its cilia to beat food particles in the surrounding water down the oral groove. The oral groove and the cytopharynx (a sac-like structure at the end of the oral groove) act as the mouth of the Paramecium.
2. Food vacuoles surround the food accumulating at the end of the cytopharynx. Lysosomes, containing digestive enzymes, fuse with the vacuoles to digest the food.
3. The digested food diffuses through the cell cytoplasm and mitochondria oxidise it to produce ATP.
4. Wastes are egested by exocytosis at the cell membrane.

Source: *http://www.mun.ca/biology/*

Other Heterotrophic Protists

- Most other heterotrophic protists, such as Amoebas, also eat by endocytosis i.e. surrounding and digesting food in food vacuoles.
- Protist feeding is the simplest example of internal digestion.
- They digest food inside their bodies.
- This is important because protists are motile.
- A protist's energy needs are too great to stay in one place and wait for their enzymes to digest food.
- If protists had external digestion like fungi and bacteria, they would have starved.

Adaptations for Feeding

- Natural selection favours organisms with adaptation for efficiently ingesting the kind of food they need.
- For example, an organism that sucks blood has different mouth parts from animals that feed on grass.
- Similarly, an ant that eats wood has different mouth structures from insects that drink nectar.

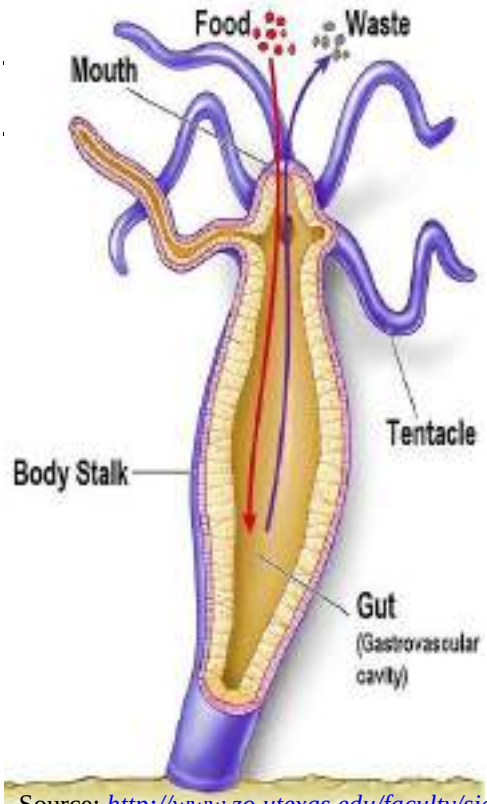
Nutrition in Animals

In Year 11, the human digestive system was studied. This year the varying digestive systems of other animals will be examined.

- All animals are heterotrophs with internal digestion.
- They all must ingest food, digest it, absorb the nutrients, and then egest any waste.
- Though, animal guts share the same basic functions, the animal digestive system is specially adapted to the animals' food and lifestyle needs.

Invertebrate Animal Digestive System

- Invertebrates are animals without backbones.
- Generally invertebrates have simple guts.
- In this section we will study the digestive system of representative from three invertebrates' phylums: Cnidarian, Annelida and Arthropoda.



Source: *http://www.zo.utexas.edu/faculty/sjasper/*

Nutrition in Cnidarians

Cnidarians have a simple **'sac-like'** gut, with only one opening and one unspecialised gut chamber which suffices the energy needs of sessile cnidarians.

- Cnidarians do not have a circulatory system to deliver nutrients – digested food diffuses from the gut to the body cells.

Cnidarians feeding steps:

1. Food is trapped and pushed into the mouth with tentacles.
2. Food is digested and absorbed in the one gut chamber.
3. Waste is ejected back and out of the mouth.

Example: *Hydra* shown on the left.

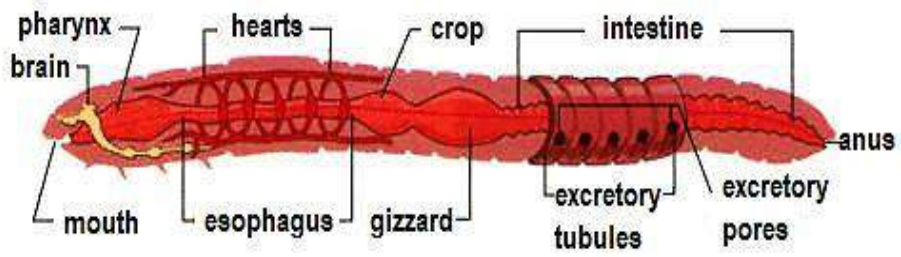
Adaptive Value of the Sac - like Gut

- The cnidarian gut is very simple since cnidarians have an inactive lifestyle.
- Simple cnidarians are sessile therefore, their cells do not need much energy.
- One gut opening and one gut chamber supplies enough food for their body cells.
- Since a cnidarian has only one gut opening, it must completely digest and absorb a meal and egest the wastes before it can eat anything else.
- An active animal cannot survive with such a simple digestive system.
- Humans need over 24 hours to fully digest a meal and egest the wastes.
- Motile animals need two gut openings to digest and absorb enough food for their cells.
- One opening ingests food and another egests wastes.

Nutrition in Annelids

- Annelids have a '**simple tube -like gut'** system.
- The annelid digestive system is more efficient compared to a cnidarian because it has two gut openings.
- In an annelid, food moves through the gut in only one direction.
- Thus, a worm can eat even while it is digesting food eaten earlier.
- An example of an annelid is the earthworm.

Earthworm Digestive System



Earthworm nutrition:

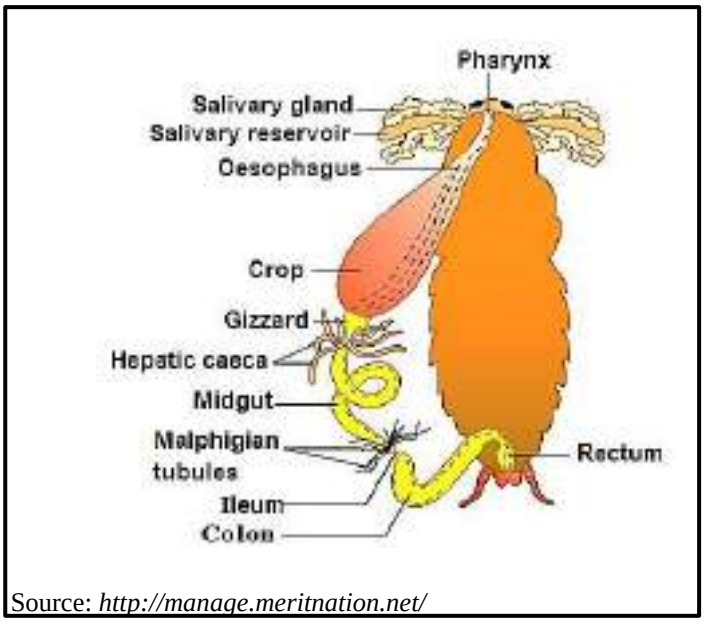
1. Earthworms suck in soil through the mouth using the muscular pharynx.
2. The oesophagus then moves the soil by peristalsis to the crop.
3. The crop stores the food until there is room for it in the gizzard.
4. The muscular gizzard grinds up food, serving the same function as our teeth.
5. The intestine both digest and absorb the bits of organic material contained in the soil. A typhlosole – a long ridge that hangs down into a worm's intestine – increases the surface area for nutrient absorption.
6. The inorganic portion of the soil and any indigestible material it contains are egested though the anus.
7. Blood absorbs digested food from the small intestine and carries it to the earthworm's body cells.

Adaptive Value of Specialised Chambers

- An earthworm has several specialised gut chambers; the pharynx, the crop, the gizzard and the intestine.
- Each chamber has a different function.
- Having specialised gut chambers allows several alimentary canal functions to proceed at the same time in different parts of the system.
- More complex animals, such Arthropods and Chordates have an even greater number of specialised chambers.

Nutrition in Arthropods

- Arthropods are the most successful animal phylum of all.
- With all of the diversity, arthropods vary greatly in their diets and therefore, in their guts. We will study the cockroach digestive system as an example.
- Arthropods have a '**complex-tube like gut'** system.
- Insects gut has a greater number of specialised chambers than an annelid gut, including special organs for secreting enzymes and absorbing water from the faeces.



Source: *http://manage.meritnation.net/*

Cockroach Nutrition

1. A cockroach *cuts up its food* with mouthparts called **mandibles** and *holds its food* with **maxillae**. Saliva from the salivary glands *moistens the food*.
2. The **crop** stores food and the **gizzard** *grinds it*, just as in an earthworm.
3. The caecum (pronounced see-cum) secretes digestive enzyme into the mid-gut. (This organ is particularly important in herbivorous insects).
4. The **mid gut** *digests and absorbs food*.
5. The **hind – gut** *absorbs water* from the faeces. This is extremely important for water conservation in terrestrial insects.
6. Indigestible food is egested out through the anus.
7. The blood absorbs digested food from the mid- gut and carries it to the insects body cells.

Intestinal Parasites

- Many animals from flies to humans get infected with intestinal parasites which obtain their food from their host animal.
- The two main types of intestinal parasites are the Helminths and Protozoa.
- Helminths are the worm-like parasites with many cells.
- Examples of helminthes are hookworms, flatworms, roundworms, tapeworms.
- Protozoa is a single-celled animal-like microscopic organism that cannot survive in the absence of water.
- A common intestinal protozoan is Giardia, Crystosporidium.
- Parasites can get entry into the intestines through the mouth from uncooked or unwashed food, contaminated water or hands, or by skin contact with larva in infected soil.
- These parasites do not need a digestive system of their own since food in the small intestine of the host has already been digested by the host.
- Intestinal worms have evolved to absorb digested food directly from their host's intestine. All they need to do is to hold on and reproduce.
- Therefore, they only have organs for attachment and reproduction.

Vertebrate Animal Digestive System

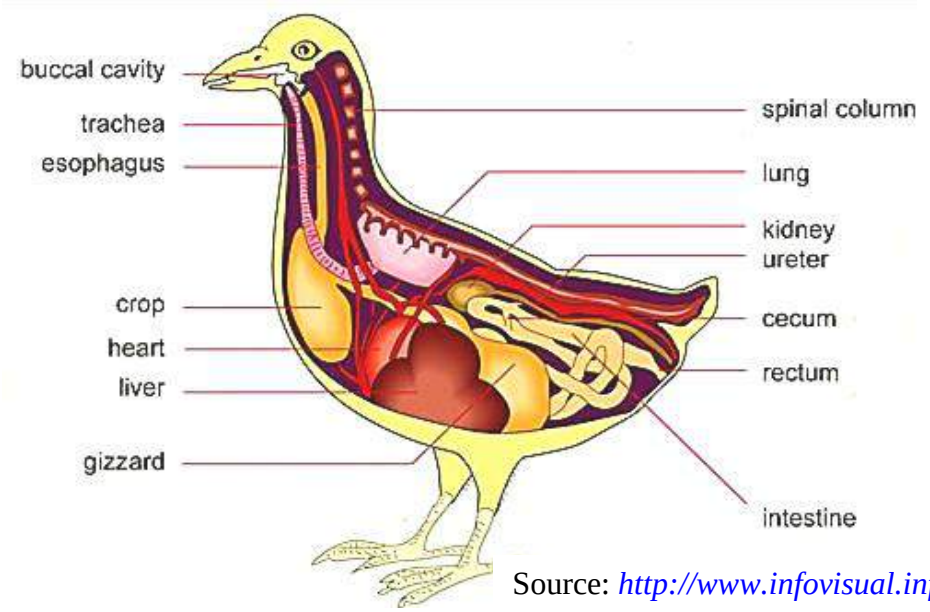
- Vertebrate animals have the most **complex digestive systems** of all.
- They have two gut opening and long alimentary canals divided into many specialised chambers unlike the digestive system of annelids and arthropods where the digested food is absorbed by the blood and nutrients are transported to all the body cells.
- In year 11, we had studied the human digestive system, this year we will focus on the digestive system of few other vertebrates such as birds, some herbivores and carnivores.

Nutrition in Birds

Adaptation for feeding

- Birds, especially those that eat fish are classed as '**gulpers'.**
- Birds have beaks that are adapted in shape and size for ingesting particular kinds of food.
- For example.
  - Hawks have sharp hooked beaks for tearing up prey.
  - Herons have long pointy beaks for 'fishing'.
  - Honeyeaters have long curved beaks for sucking flower nectar.
  - Parrots have short strong beaks for cracking seeds.
- Birds **do not** have teeth because they are too heavy and will add to the weight during flight.
- Instead, birds have muscular **gizzard**s for grinding up food. (Most birds eat small stones to help their gizzards grind up food) they also have a crop for food storage.
- Otherwise, a bird gut is similar to the guts of the other vertebrates.

Bird Digestive System



Source: *http://www.infovisual.info*

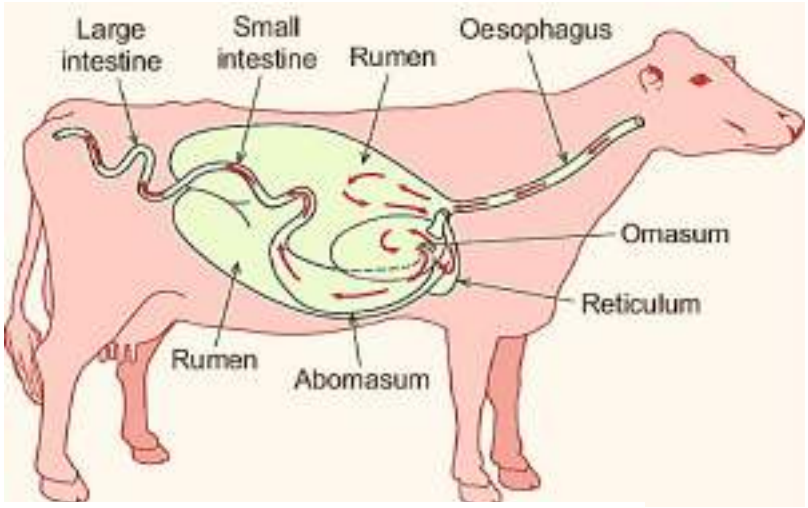
1. **Mouth**: food enters here.
2. **Oesophagus (Gullet)**: transports food from the mouth to the stomach.
3. **Crop**: a pouch in the oesophagus that stores food temporarily before moving it to the stomach.
4. **Stomach (Proventriculus/ Gizzard):** principally the organ where food is broken into smaller units. It has two parts; **Proventriculus**- stores food.
   Gizzard - muscular part of the stomach that uses grit (sand/ gravel) to grind grains and fibre into smaller particles.
5. **Small Intestine** – it has three parts; duodenum, jejunum and ileum- aids in digestion and nutrient absorption.
6. **Liver**: the largest glandular organ in the body that aids in the metabolism of carbohydrates, fats and proteins.
7. **Cecum**: bacterial action in the cecum helps breakdown undigested food passing through the intestine. The cecum turns into the large intestine, which connects with the cloaca.
8. **Large Intestine**: primarily functions to absorb water, dry out indigestible foods and eliminate waste products.
9. **Cloaca**: Where the digestive, urinary and reproductive systems meet.
10. **Vent**: the external opening of the cloaca that passes waste out.

Herbivore and Carnivore Guts in Mammals

- Human guts cannot digest plants. If eaten, it would just pass through the alimentary canal and out of the anus.
- This is due to plants cells having very tough cell walls made of cellulose.
- The cellulose is not digested easily by the human digestive system.
- The human digestive system lacks the enzymes that are capable of cellulose digestion.

Nutrition in Cattle

- Cattle belong to a class of animals known as ruminants.
- Due to the double chewing (regurgitation) in cows they are a good example of '**masticators**'.
- They have four compartments to their stomach and chew their cud.
- In addition, ruminants have an unusual configuration of teeth.
- Their small and large intestine are designed to handle large volumes of material.
- Cattles are evolved to exist on large amounts of fibre.
- They do not do well on all grain or high fat diets.



Source: *https://lh6.googleusercontent.com*

- Despite these adaptations for plant digestion, the faeces of cows and other herbivores will show that some grass has still passed through the gut *undigested.*

Adaptation in herbivorous mammals for digesting plants

Feature	Purpose
Wide, flat teeth	– For grinding leaves between their teeth like humans
Double chewing	– Herbivores chew plant material, swallow it and then regurgitate it to chew it again later.
Symbiotic bacteria	– Herbivores have special cellulose-digesting bacteria that live in their guts. – These bacteria help the animal break down the cellulose in the cell walls. – In exchange, the herbivore provides the bacteria with food. Often these bacteria are housed in the caecum.
Very long intestine	– This allows herbivores more time to digest and absorb the food.

Comparison of Vertebrate Carnivores and Omnivores with the vertebrate herbivore nutrition	
Vertebrate Carnivores (eat other animals) E.g. Lions	
Feature	**Purpose**
Sharp teeth	For catching and tearing prey
Shorter intestine	Allows for faster digestion
Simple digestion	Since all the digestive juices for digestion of flesh is present.
Vertebrate Omnivore (eat both plants and animals) E.g. Humans	
Feature	**Purpose**
Sharp canine teeth	For tearing flesh
Flat molar teeth	For grinding food (plants)
Caecum	Hosts cellulose digesting bacteria

Nutrition Methods of Heterotrophs

Nutrition Method	Adaptive Value
External digestion	- Food is digested outside the body so there is no need for digestive organs; - Appropriate only for small sessile organisms because the organisms must stay on the food until it is completely digested. *e.g in saprophytic bacteria and fungi.*
Internal Digestion	- Food is digested inside the body so that the organisms can move about while food is being digested and absorbed. - Appropriate for motile organism. - *e.g in animals and protists*
Food vacuoles	- Food is enclosed and digested in a cell's food vacuoles; - Appropriate for motile unicellular organisms that have cell organelles. - *e.g in protists*
Gut-sac-like	- Only one gut opening and one gut chamber so food is ingested and wastes egested through the same opening. - Food must be completely digested and absorbed and the wastes egested before the animal can eat again; sufficient to supply nutrients to cells of sessile animals. - *e.g in cnidarians*
Gut –tube **(with specialised gut**	- Two gut openings so food moves one-way through the gut - This digestive system allows consumption of large amounts of food as it allows animals to eat continuously. - *e.g in most animal phyla, including annelids, arthropods and chordates.*

chambers)	- Alimentary canals of animals with two gut opening have specialized sections along the gut. - Each section doing a different digestive task - this speeds digestion as it allows many different digestive functions to go on at the same time. *e.g* of some specialised chambers: crop for food storage, gizzard for grinding food, caecum and glands for enzyme secretion, hind gut for absorption of water.

Evolutionary Trends in Nutrition

- The more recently evolved organism groups have more complex nutrition methods.
- For example, a mongoose has two gut openings with many specialised chambers while a mushroom can survive by secreting enzymes and then absorbing the nutrients.
- The factor here is *speed*.
- Motile organisms need more energy and they need it more quickly than sessile organisms.
- ***The faster organisms move, the more efficiently its digestive system must process food.***

- As the ability for speed increases, the following trends in the nutrition methods of organisms can be observed:
  1. Increasing capacity for ingestion.
  2. Increasing specialisation of gut chambers.
  3. Increasing surface area for nutrient absorption.
  4. Specialisation of a transport system to carry nutrients from the digestive system to body cells.

Nutrition and Other Body Systems

- The organ system of multicellular organisms cannot function on their own/ alone.
- Nutrition often depends upon other body systems for the following functions.
  1. The organisms must be able to find food (or in the case of autotrophs, inorganic materials for making food).
  2. The organism must distribute the nutrients to all body cells once it has digested food.
  3. The organisms must take in and distribute oxygen to decompose the nutrients in cells by respiration.
  4. The organisms must excrete the metabolic wastes created by breaking down the nutrients.
- Thus, the nutrition system of multicellular organisms usually works together with the nervous, transport, gas exchange and excretion systems.

SELF TEST

1. Give two examples of organisms that fit in each of the following consumer categories;
   (i) predator, grazer, parasite, saprophyte.
   (ii) minute particle feeder, gulpers, masticators, wallowers, filter feeders, fluid feeders

2. Give at least two adaptations in plants that allows them to obtain maximum:
   (i) Sunlight
   (ii) CO_2
   (iii) Water

3. Why do plants need magnesium?

4. Fungi and bacteria have external digestion.
   (i) Explain what external digestion means.
   (ii) What is the potential disadvantage of external digestion?
   (iii) Why is this disadvantage not a problem for fungi?

5. Heterotrophic protists take in food by surrounding it with a piece of cellular membrane, forming a vesicle. What is this kind of transport called?

6. Describe two ways grasshoppers are adapted for eating grass.

7. What is the advantage of a gut with two opening over a gut with just one?

8. Why do you think insects do not have external digestion or a sac – like gut?

9. What is the advantage of a gut with specialised chambers?

10. Make three points of comparison between the digestive system of a jelly fish and an earthworm. Relate each point to the lifestyle of the organisms.

11. Why doesn't an intestinal parasite have a digestive system?

12. Why don't birds have teeth? How do they grind up their food?

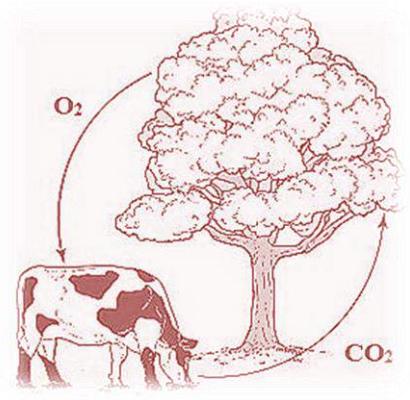
13. Why is most plant material so difficult to digest? Describe three ways herbivorous mammals are adapted to digest plants.

14. For each of the following organisms, describe how digested food reaches their body cells: a hibiscus plant, a paramecium, a coral polyp, an earthworm, a mosquito, a human.

15. Over time, nutrition methods have evolved to be more efficient and complex.

    (i) In what ways have nutrition methods become more efficient?
    (ii) What evolutionary trend has led to selection for efficient and complex methods?

BI 12.1.4.2 GAS EXCHANGE



- Organisms release energy from the food they digest by "burning" the food with oxygen.
- This process is called *respiration*, as seen earlier in **Nutrition**.
- Respiration occurs in both plants and animals.

Organisms must take in oxygen and then excrete the carbon dioxide waste produced, as the respiration reaction releases energy from glucose.

- The gas exchange system of each kind of organism is particularly adapted to its environment and way of life.
- The more energy an organism requires, the more oxygen it needs to oxidise food.
- The more oxygen it needs, the faster it must exchange gases.
- Active organisms need a large energy supply and so must have a very efficient gas exchange system.
- On the other hand, sessile organisms do not need as much energy and so their gas exchange systems are less efficient.

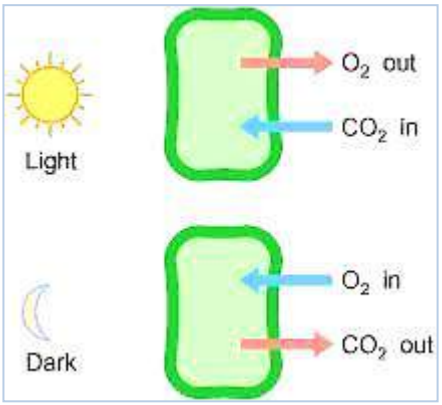
Gas Exchange in Plants

- Plants need carbon dioxide for photosynthesis and oxygen for respiration.
- They rely solely on direct diffusion for gas exchange.
- Plants are sessile and do not need rapid gas exchange therefore, they are adapted for a slow diffusion method.

Factors affecting rate of gas exchange in plants	Efficient gas exchange systems must
❖ The area available for diffusion. ❖ The distance over which diffusion occurs. ❖ The concentration gradient across the gas exchange surface. ❖ The speed with which molecules diffuse through membranes.	❖ have a large surface area to volume ratio ❖ be thin ❖ have mechanisms for maintaining high concentration gradients ❖ be permeable to gases.

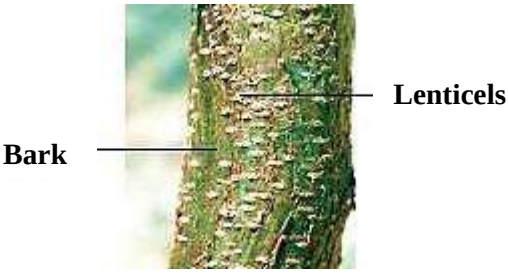
Flowering plants exchange gases through their **stomata** present on the leaves:

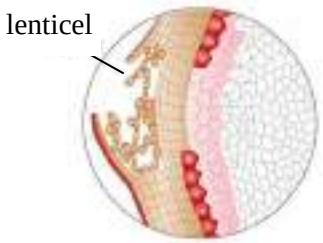
- In the light there is a net intake of carbon dioxide for photosynthesis and a net output of oxygen from respiration.
- In the dark there is a net intake of oxygen for respiration and a net output of carbon dioxide.
- Terrestrial plants get plenty of air so they usually have stomata on the bottom of their leaves.
- Aquatic plants have their leaves near or under the water, but they also need to breathe.
- Plants that float on the surface of the water have their stomata on top, where they have access to air.
- Plants that live completely under water gather CO_2 from the water. When they release O_2 you can see tiny air bubbles gathering around them.



Source: *http://www.rsc.org*

- *Woody plants* use **lenticels** for exchanging gases.
- Lenticels are raised lose cork tissue in woody stems, roots and some fruits which function in gas exchange for aerobic respiration.
- Live non-photosynthetic cells tissue cells below the dead cork layer need oxygen gas.
- They also need to get rid of carbon dioxide waste gas.
- Lenticels allow oxygen in and carbon dioxide out.



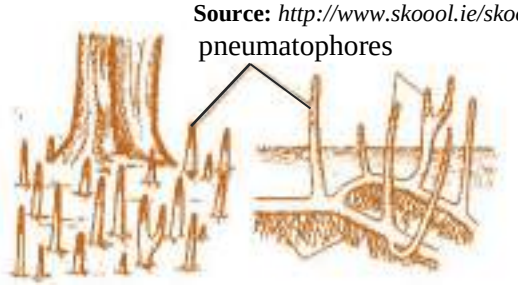


Source: *http://www.skoool.ie/skoool/*

Plants can open their stomata to get gases by direct diffusion but they face water loss at the same time. Therefore, at night and during water shortages plants conserve water by closing their stomata.

Gas exchange in Pneumatophores

Pneumatophores are erect roots with specialized structures that allow for respiration. E.g. root mangroves.



Adaptation for Gas Exchange in Plants

Plants have several adaptations that allow gases to diffuse in and out relatively quickly. These adaptations include:

- **Stomata,** small openings in the underside of most leaves, which allow gases to diffuse in and out.
- **Air spaces** in the spongy layer of a leaf to allow carbon dioxide to diffuse more quickly to the photosynthesising palisade layer.
- **Thin leaves with broad surfaces** to maximise surface area to volume ratio for faster diffusion to cells.
- **Lenticels** (small holes in the bark) in woody plant stems and small gaps in the stem surfaces of herbaceous plants that allow plants to respire.

Gas Exchange in Animals

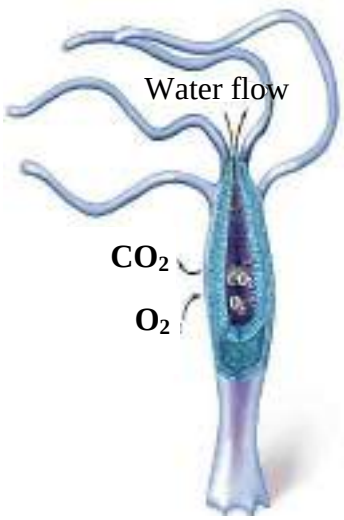
- Small and sessile organisms can often get enough oxygen by diffusion alone.
- Larger, more active organisms must have a specialised organ system for exchanging gases quickly.
- Gas exchange systems in most active animals rely upon transport systems to deliver oxygen to cells and to carry away carbon dioxide waste.
- All organisms even those with specialised gas exchange systems, depend upon diffusion to exchange oxygen and carbon dioxide across the respiratory surfaces.
- To assist this diffusion, the respiratory surfaces (lungs, skin, and gills) of all animals have the following three adaptations:

1. The respiratory surfaces are ***moist*** *to dissolve* oxygen and carbon dioxide.
2. They have a **large surface area** for gas exchange.
3. They are ***extremely thin*** so gases can pass through more quickly.

Gas Exchange in Invertebrates

Gas Exchange in Cnidarians – direst diffusion

- Cnidarians are well aquatic and relatively sessile.
- Some common cnidarians include corals, sea anemones and jelly fish.
- These animals rely on simple diffusion to exchange oxygen and CO_2 between cells and surrounding water.
- A cnidarian's cells do not need much oxygen since these animals are inactive.
- Thus, cnidarians do not need a transport system to carry gases to and from their body cells.
- Oxygen and carbon dioxide move to and from a cnidarian's body cells by diffusion alone.



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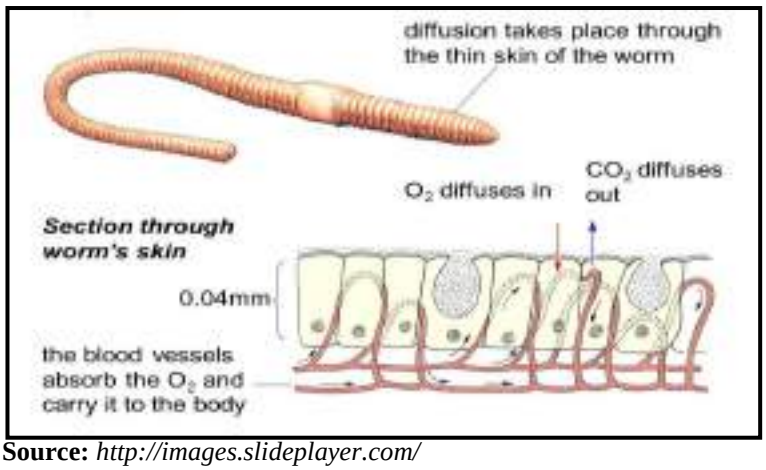
Gas exchange in Annelids – diffusion through the skin

- Annelids (segmented worms), exchange gases between the air and the blood by direct diffusion.
- For this diffusion to occur, it is very important for the skin to be moist.
- The skin is kept moist by body's physiological processes such as secretion of moistening fluid by the mucus gland and by behavioural processes of the worms living in damp areas, avoiding sunlight and feeding at night.
- The worm's blood carries oxygen to the body cells and carbon dioxide away from the cells.



Source: *http://images.slideplayer.com/*

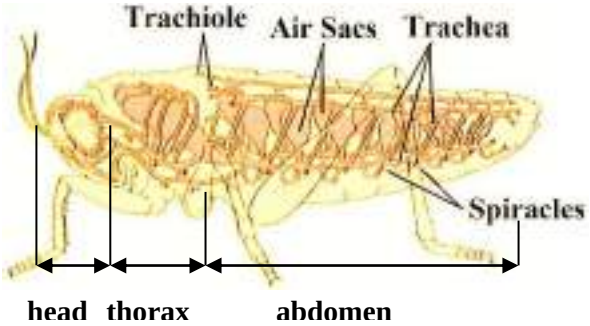
- If an annelid's skin surface dries up and the oxygen diffuses into the blood, the worm will suffocate and die.
- However, desiccation poses little threat to worms in their natural underground habitat.
- Annelids mostly burrow into soil to avoid desiccation due to over exposure to air and sunlight.

Gas Exchange in Insects – Diffusion through a tube system

- Insects cannot survive on gas diffusion through the skin because:
  - Most insects live above the ground and so cannot keep their skin moist.
  - They are so active that diffusion through their outer surface alone cannot provide enough oxygen to their body cells.
- Insects have a unique gas exchange system.
- Even though insects have a transport system, insect blood does not carry oxygen to body cells.
- Instead, insects have a separate system of air pipes called **trachea** and **trachioles** through which air diffuses to and from body cells.
- The openings to these pipes, usually found on the underside of an insect, are called **spiracles.**

Steps of gas exchange in insects:

- Air enters through the external openings in the thorax called the spiracles.
- The air moves into the trachea and branches out into the trachioles. These trachioles are connected to the body cells. Movement of the abdomen, thorax and air sacs assist air movement.
- Air (oxygen) reaches the body cells through the trachioles.
- Similarly, CO_2 diffuses out of the body.



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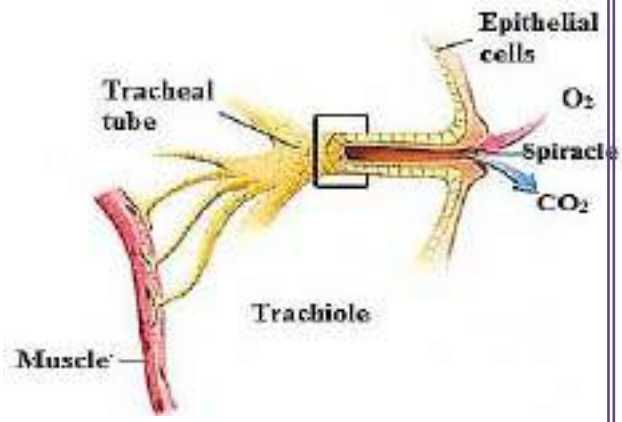


Source: *https://classconnection.s3.amazonaws.com*

Adaptation of insects for water conservation

In order to reduce water loss from the moist walls of the trachea most insects;

- partially close their spiracles when they are not active.
- The trachioles pass the cells just like capillaries pass by each cells in humans, this prevents loss of moisture.
- The trachioles are thin and moist at all times allowing for faster diffusion of gases between the trachioles and the body cells.
- Larger, flying insects sometimes pump their abdomen in and out to aid the movement of air into their spiracles.

Adaptive Value

- This form of gas exchange through a tube system is not suitable for larger and active animals.
- The body volume of larger animals is too great to be supplied by this kind of system.
- They need oxygen to be actively pumped to body cells.
- However, insects are quite small, so the gases do not have to diffuse very far to reach each of their body cells.

Gas Exchange in Vertebrates

- Vertebrate animals tend to be quite active hence, all vertebrates have specialised respiratory organs and a pumped transport system to meet the energy demand of their body processes.
- Vertebrates actively pump or suck the surrounding air (or water, in the case of fish) to get oxygen into their food quickly by the process of breathing or inhalation.
- Vertebrates are capable of adjusting the speed of gas exchange to the rate of their cells' respiration.
- For example, your breathing rate increases when you run because active muscles cells need plenty of energy and your breathing rate decreases when you are sleeping because resting cells do not need much oxygen.

The adjustment of the breathing rate by the vertebrates to the respiration rate of their cells is another example of homeostasis

- Transport of gases to and from gas exchange surfaces uses blood or the circulatory system in most animals (except for insects), therefore, gas exchange and transport systems are in close contact.
- Therefore, for effective gas exchange, vertebrate respiratory surfaces must;

  - ✓ **be well supplied with blood capillaries**
  - ✓ **be thin and moist at all times**
  - ✓ **have a large surface area.**

Gas Exchange in Fish

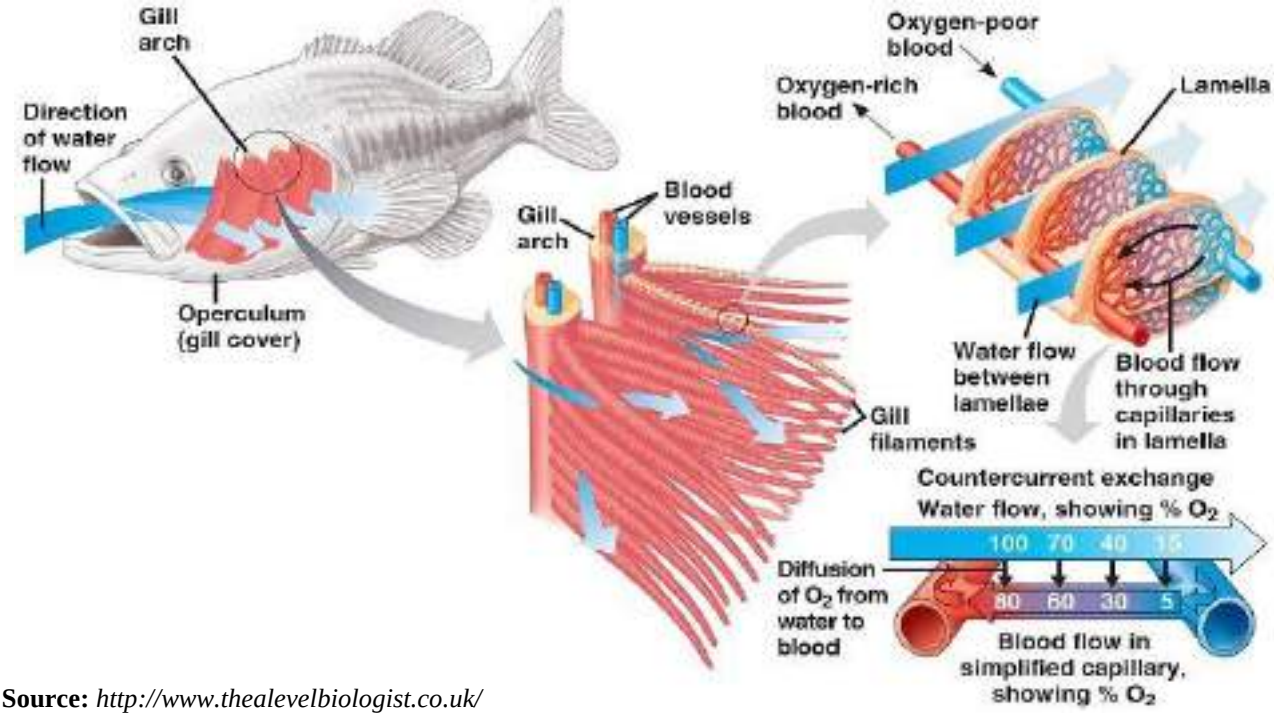
- Fish have internal **gills** to exchange gases with water while in tadpoles the gills are located externally.
- Gills rest outside a fish's body, though they are protected under gill covers.
- Exchanging gases with water is more difficult than exchanging with air because;
  - Water contains less oxygen than air.
  - Water is harder to pump over the respiratory surface because it is denser.
- Fish have several adaptations for overcoming these problems.

Fish Adaptations for Getting Oxygen from Water

- Fish constantly pump fresh water over their gills using a muscular pharynx.
- Tiny ridges called **lamellae** on folds called **gill filaments** greatly increase gill surface area for gas exchange.
- Structures called *gill rakers* trap any bits of food.
- Gills dependent on the buoyancy of the water for support.
- Gills are packed with blood capillaries.

The direction of the blood flow in the gills is in the opposite direction to the flow of water on the gills. This ***counter current flow*** maximizes the concentration gradient thus maximizing the diffusion of O_2 from the water into the blood and CO_2 from the blood into the water.

Gas Exchange in Fish



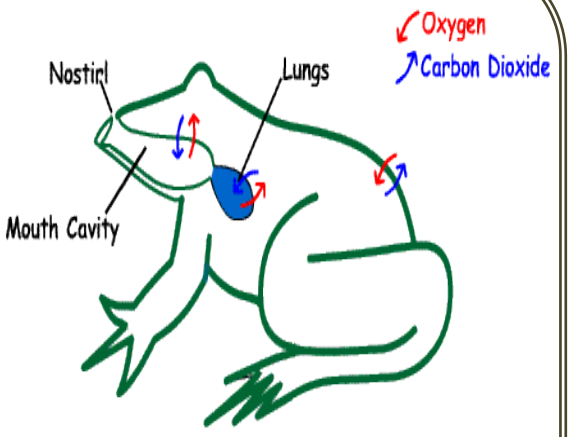
Source: *http://www.thealevelbiologist.co.uk/*

Adaptive Value

- Since all the fish are aquatic, their respiratory system is specially adapted for exchanging gases with water and would suffocate quickly out of water.
- Out of water, fish gill filaments stick together greatly reducing the surface area for gas exchange.
- The gills quickly dry up and then no longer able to dissolve gases for exchange.
- Fossil remains suggest that fish were the first vertebrates to evolve and have been around for approximately 400 million years longer than we humans.

Gas Exchange in Amphibians –gills, lungs and skin

- Amphibians were the first vertebrates' adapted for life on land.
- They form the evolutionary link between fish and land vertebrates.
- Young amphibians, i.e. **tadpoles** survive in water using external ***gills*** for gas exchange.
- Adult amphibians live on land, relying partly on their lungs.



Source: *https://upload.wikimedia.org/*

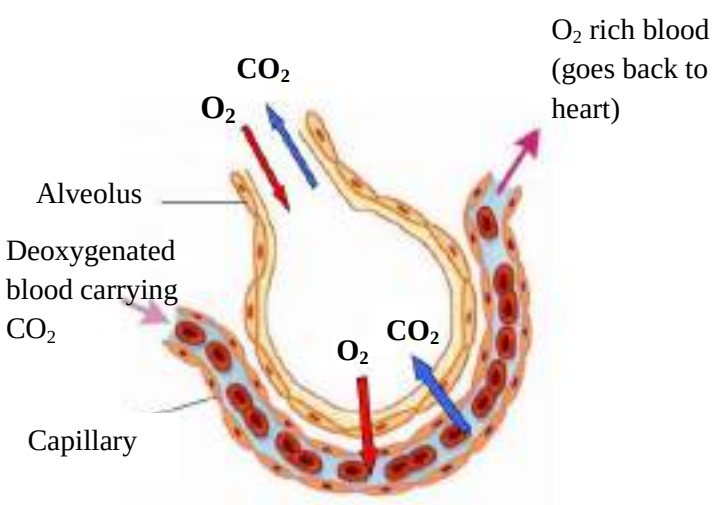
- The land- dwelling adult forms, use their moist skin and their lungs for gas exchange. For effective diffusion amphibians must keep their skin moist at all times.
- To stay moist, toads and other amphibians often hide under rocks or logs until it rains or until after the sun sets.

Gas Exchange in Reptiles, Mammals and Birds – lungs

- Reptiles, such as lizards and snakes, were the first vertebrates adapted for living their entire lives on land.
- Evidence suggests that birds and mammals later evolved from reptiles.
- These three vertebrate classes have lungs and muscles specialised to suck air.

Adaptation for Efficient Gas Exchange

1. The alveoli in the lungs have thin, moist surfaces.
2. The alveoli create a large surface area for gas exchange.
3. Their lungs are extremely well supplied with blood capillaries.



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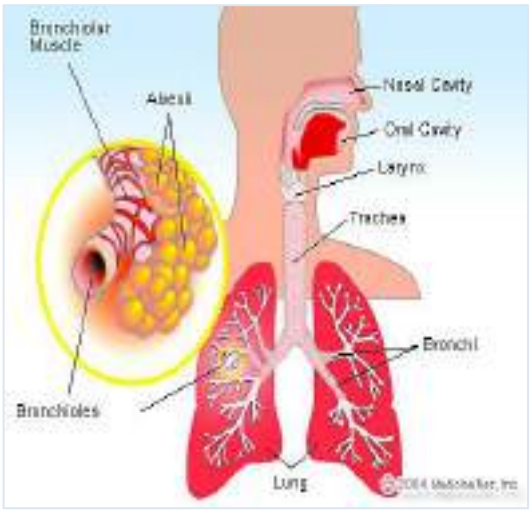
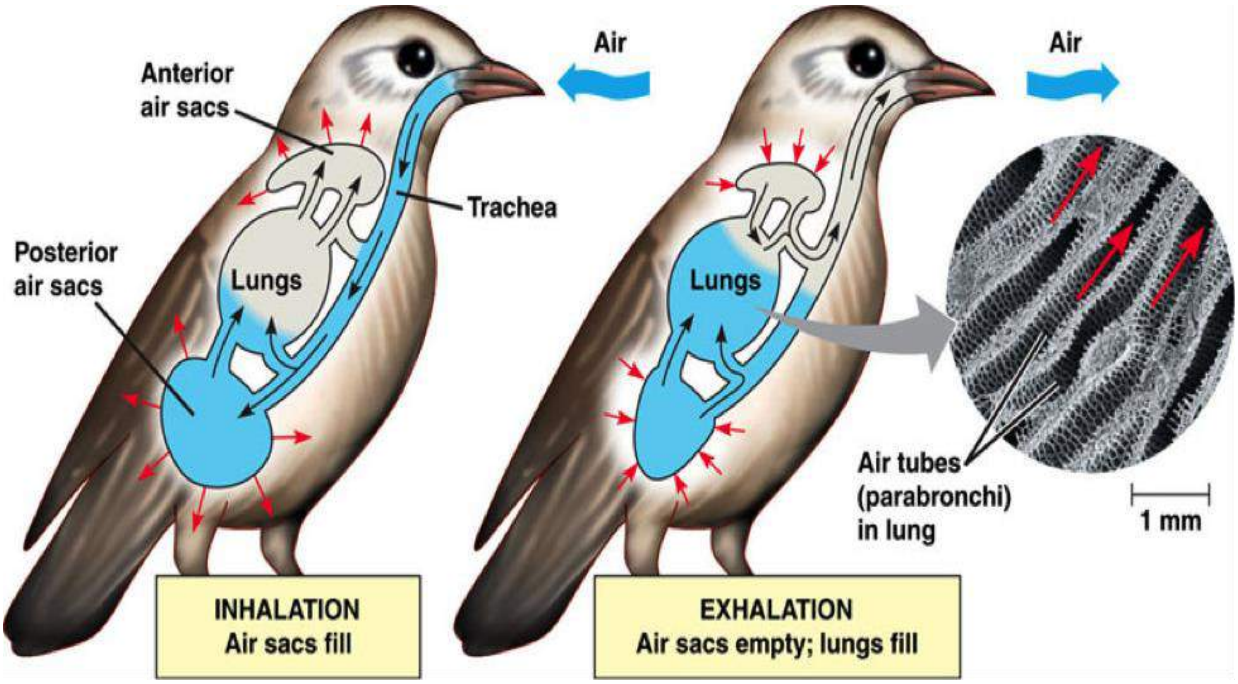


Source: *http://www.emedicinehealth.com*

- ❖ Birds are the most active of the mentioned three vertebrate groups.
- ❖ Birds have evolved the most efficient gas exchange system of all animals on Earth.
- ❖ Other land vertebrates suck air into dead- end sacs and then force it back out the same path.
- ❖ Birds instead have one way air flow through small tubes in their lungs.
- ❖ This way, birds do not just draw air into their lungs, but through them.
- ❖ Birds need this efficient air- supply system in order to provide their muscles with oxygen to get the energy needed for flying.

Gas Exchange in Birds



Source: *http://www.scienceforums.net*

Adaptations for Gas Exchange		
Gas Exchange Method	**Organisms Group**	**Adaptive Value**
Direct Diffusion – no respiratory organs or connection with a transport system.	Plants, bacteria, protist, fungi, cnidarians	Supplies sufficient oxygen to the cells of small or sessile organisms.
Diffusion through the skin into blood.	Worms, adult amphibians	Supplies blood with oxygen in organisms that are able to keep their skin moist at all times.

Gas Exchange Method	Organism group	Adaptive Value
Diffusion through tube network – air diffuses to body cells through tubes, no connection to transport system.	Insects and spiders	Supplies sufficient oxygen to the cells of small organisms conserves water since tubes are inside the body.
Gills – gas exchange between water and the blood capillaries inside gills, gills hang outside of the body	Crustaceans, bivalves, immature amphibians	Adapted for exchanging gases with water (gill filaments, water pumped over gills, counter-current blood flow in gills)
Lungs – gas exchange between inhaled air and the blood capillaries supplying the lungs; lungs are inside the body	Adult amphibians, reptiles , mammals, birds	Adapted for very efficient exchange of gases with air in order to supply cells of large active land animals; conserves water

Evolutionary Trends in Gas Exchange

- The more an organism moves the more energy it uses energy.
- For example, a jellyfish drifts around in the ocean and occasionally pumps water to push itself forward and due to its inactive lifestyle, the jellyfish suffices its gas exchange needs by diffusion only.
- A fish on the other hand, darts around quickly looking for food and evading predators and hence, it needs a more active form of gas exchange system compared to the jelly fish.
- The more energy it uses, the more oxygen it needs and the more carbon dioxide waste it produces.
- As speedier organisms evolved, they needed more efficient gas exchange systems which actively pumped air or water and linked with a transport system.
- Additionally, terrestrial organisms evolved adaptations for reducing water loss from their respiratory surfaces.

SELF TEST

1. Why do organisms need oxygen?

2. Briefly describe how each of the following organisms is adapted to get the oxygen for its cells needs: *a hibiscus bush, a jellyfish, an earthworm, a housefly, a toad, a chicken*.
   a. Water lily leaves, which float on the surface of the water, have stomata on the upper surfaces of their leaves instead of the lower. Why are their stomata on the upper leaf surfaces?

b. How would stomata arrangements be a problem for land plants?

3. Every organism on the planet uses up oxygen in respiration, yet we have not run out of oxygen. Explain why.

4. List the four respiratory surface adaptations for gas exchange that every vertebrate has.

5. Bacteria and protists have no specialised structures for gas exchange. Gases simply diffuse in and out of the cells.
   a. What animal phylum also depends upon direct diffusion of gases to and from cells?
   b. Explain why most animal groups cannot rely on direct diffusion to their cells for their gas exchange?

7. Earthworms reflexively move away from light. How is this behaviour adaptive for their method of gas exchange?

8. Compare insect's method of gas exchange to that of an earthworm. Relate the differences to the animals' lifestyles.

9. Explain why an elephant could not survive with the trachea and spiracle system of gas exchange that insects use.

10. Why it is important for insects to partly close their spiracle when they are not very active?

11. Why do vertebrates need a particularly efficient method of exchanging gases?

12. Give two reasons why land animals cannot use gills for gas exchange.

13. Choose three organisms you have studied and explain the adaptation of each for increasing their surface area for gas exchange.

14. Choose three terrestrial organisms you have studied and explain the adaptations of each for increasing their surface area for gas exchange.

15. Explain why getting oxygen from water is more difficult than getting it form air and describing how fish overcome these difficulties.

16. Why does a vertebrate's breathing rate vary with its activity level?

17. What is the primary difference between lungs and gills? How is the difference adaptive?

18. Dolphins and whales, both aquatic mammals, have a small breathing hole in the middle of their backs. Explain how the location of this hole might be adaptive.

19. In what way are the lungs of a 'bird' more efficient than those of a mammal or reptile? Why do birds need this more efficient respiratory system?

20. The term 'gas exchange' refers to the exchange of what gases?

BI 12.1.4.3 TRANSPORT

- All organisms have adaptations for getting nutrients and exchange gases.
- Complex organisms have a transport system that connects with their nutrition and gas exchange systems.
- This system delivers nutrients and oxygen and carries away cellular waste.
- In some organisms, the blood carries disease-fighting materials and distributes hormones.
- The transport system of each organism is adapted to its environment and way of life.
- Some organisms do not need a separate system at all if they are very small or inactive.
- Diffusion alone takes care of their transport needs. Other organisms are active and need an efficient transport system to supply their cells with food and oxygen

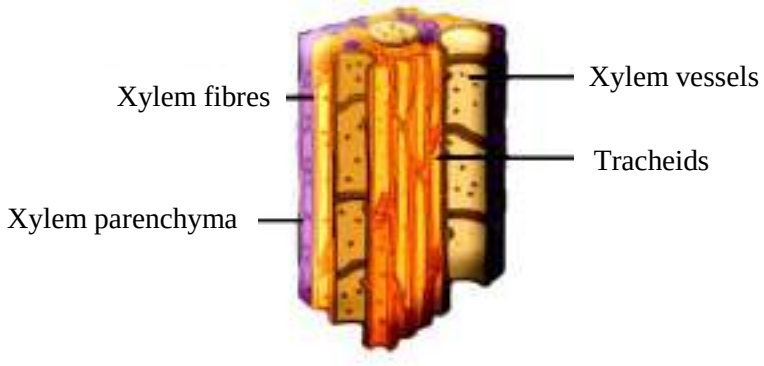
TRANSPORT IN VASCULAR PLANTS

- Vascular plants are plants with specialized structures for conducting water and food
- Plants absorb water and minerals through their roots and transport them to the leaves and stems for metabolic use, e. g. photosynthesis.
- Examples of vascular plants include flowering and seed plants, trees, ferns, conifers, etc
- Xylem transport water and minerals from roots to shoots.
- Phloem transport sugars and other organic nutrients from where they are produced or stored to where they are needed for growth and metabolism.
- Algae and mosses lack a vascular system, therefore, they live in wet habitat where water and food diffuse directly into their cells.

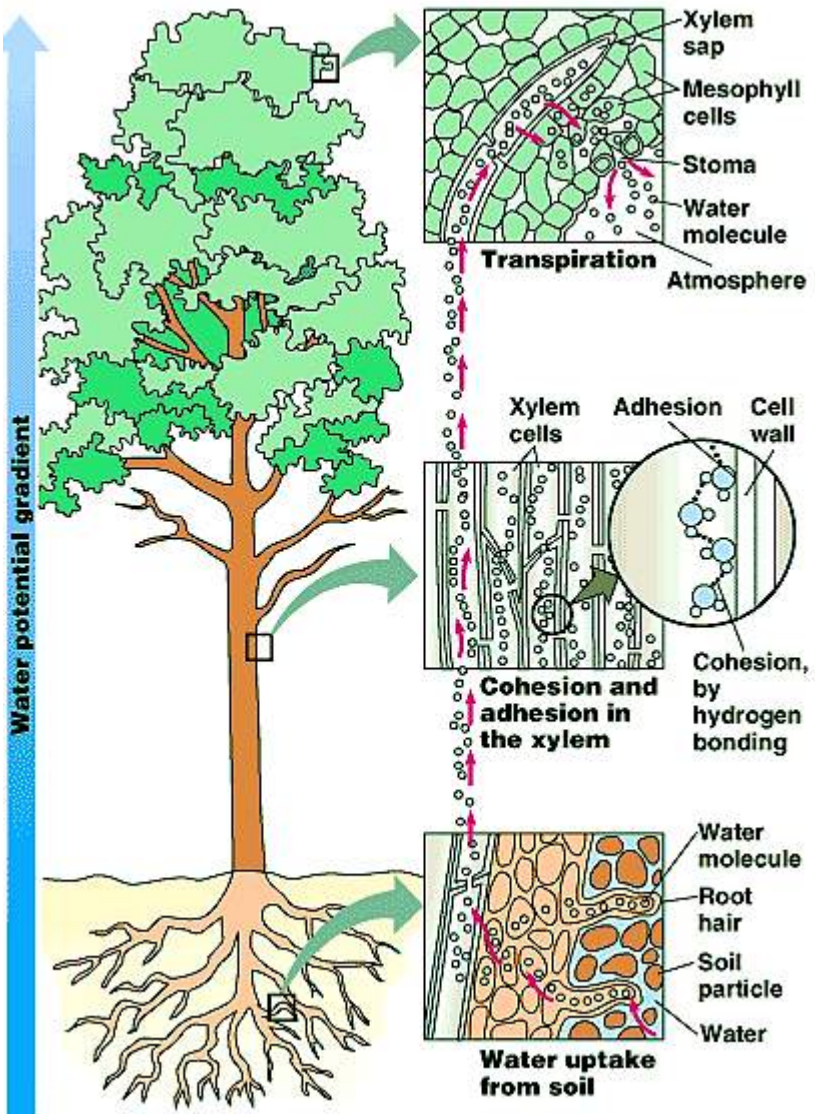
The deepest root of a mango tree might be over 60 meters from the highest leaves. Yet water and minerals must get up to these leaves and food must get down to the roots and other plant parts. Tube systems of xylem and phloem carry water, minerals and food through the plant.

Xylem – the transport of water and minerals

- Xylem cells are specially adapted for carrying water and dissolved minerals through plants.



. Water Transport



Source: *http://plantcellbiology.masters.grkraj.org*

- Water manages to reach the top of every tall tree by being 'sucked' up by the xylem as water evaporates from the leaves.
- This is called the **cohesion theory of water transport.**

The Cohesion Theory of Water

1. **Water evaporates from the leaves via transpiration, mostly through open stomata.**
2. **The pulling action of transpiration sucks water up through the xylem tubes.**
3. **Since water molecules stick together (i.e., they are cohesive), when water molecules leave the plant through the stomata, they pull up molecules from below to take their place.**

- So, according to this theory, water moves up through xylem by a combination of ***transpiration pull*** and ***water cohesion***.

- Additionally, the higher concentration of minerals in roots than in soil causes water to move into roots by **osmosis**.
- The force of water moving into roots is called **root pressure**. This pressure helps to push water up the xylem.
- Plants need enough water;
  - to remain **turgid**
  - to use in photosynthesis
- They also must lose a lot of water by transpiration in order to pull water up from the roots.

Mineral Transport

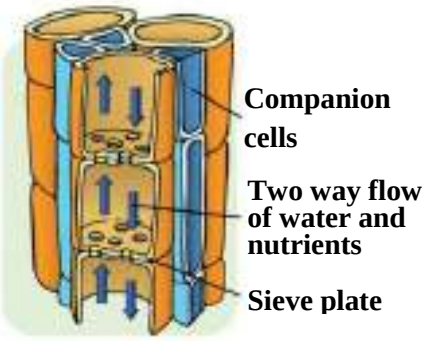
- Water can move easily through the cell membrane of root cells by osmosis.
- Dissolved minerals, however, are charged and so cannot pass through the phospholipid bilayer of cell membranes.
- Also, the concentration of minerals is often higher inside the plants than outside.
- Thus, root cells depend on active transport to bring minerals into the xylem.
- The active transport of minerals into the roots requires ATP from respiration, but food is made far away in the leaves.
- Roots get the glucose required to make this ATP through the phloem.

Phloem

- Phloem cells are adapted for carrying food from leaves to all other parts of plants.
- Plant starch (carbohydrate) is produced by photosynthesis. These starch molecules are too large to pass through cell membranes.
- Starch must be hydrolysed into sucrose for transport through phloem.
- The solution of water, sucrose and other food molecules (organic materials) in the phloem is called **sap.**
- The transport of the sap is called **translocation.**
- Sap in the phloem is under very high pressure (as much as five times higher than air pressure in a car tyre).
- This pressure helps push sap through phloem.
- Phloem tissue is made of two kinds of cells; **sieve cells** and **companion cells**.

Sieve cells

- The sieve cells are continuous tubes throughout the plant.
- The end wall of this continuous tube has lots of little holes in the cells walls at both ends so the sap can pass through more easily.
- These porous ends of sieve cells are called sieve plates.



Source: *https://dr282zn36sxxg.cloudfront.net*

Companion cells

- The companion cells provide the sieve cells with ATP for active transport.
- Sieve cells can carry sap in their own direction, companion cells direct sieve cells to carry food to stems and roots for storage or to cells that need it for energy.

Transport in Animals

- Small or sessile organisms do not actually need a transport system.
- They can often get the materials they need by diffusion alone.
- Larger, more active organisms must have a specialised organ system for bringing food and oxygen to and waste away from their cells.
- All organisms, including those with specialised transport systems, depend upon *diffusion* to move materials *in* and *out* of body cells.

Transport in Invertebrates

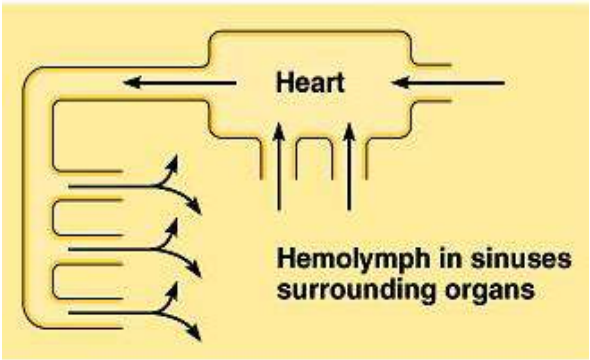
Transport in Cnidarians – direct diffusion

Cnidarians rely on direct diffusion to supply their cells with nutrients from their gut obtained from the surrounding water.

- Since cnidarians are sessile and diffusion is a slow process, they do not require an efficient transport system.
- They do not use up nutrients and gases or produce wastes very quickly like other larger animals

Transport in Arthropods and Molluscs- Open circulation

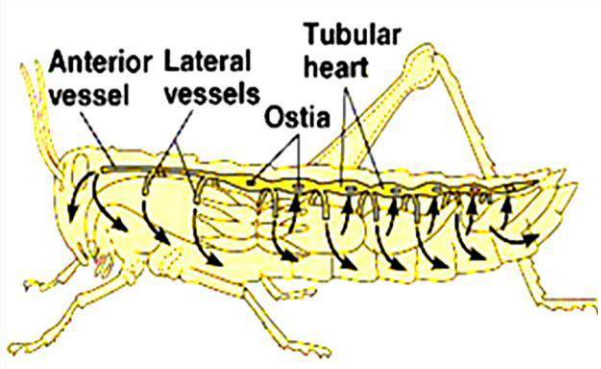
- Arthropods (such as insects and shrimp) and most molluscs' (such as snails and clams) have open circulation.
- Open circulation means that the blood is not enclosed in vessels, but instead flows in an open body cavity, bathing body cells directly.



Source: *https://lh6.googleusercontent.com/*

Transport in a Grasshopper

- In a grasshopper, a long heart pumps blood into an open body cavity called a **haemocoele (**hee-mo-seal).
- The blood in the haemocoele bathes the body cells directly.
- It is not enclosed in blood vessels.
- Arthropod blood transports nutrients and cellular wastes.



Adaptive Value for a closed circulatory system

- Most animals have closed circulatory systems.
- Vessels contain their blood. Their blood never touches body cells directly.
- A closed system is necessary in larger animals for the following.
  1) Artery contraction can adjust the amount of blood flowing to each part of the body according to its activity level.
  2) A large animal filled with blood would suffer great difficulty walking with so much fluid sloshing around. If it ever tripped and felt it would burst open.
  3) Blood flow through a body cavity is too slow to supply enough oxygen to the cells of larger animals.
- For small organisms such as insects, the blood flow through a body cavity is fast enough to supply sufficient nutrients to their body cells.
- Additionally, insects do not rely upon their transport system to supply oxygen to their cells.
- Open circulation is not quick enough.
- Insects and spiders have a separate ***tracheal system*** that allows gases to diffuse directly to their cells.

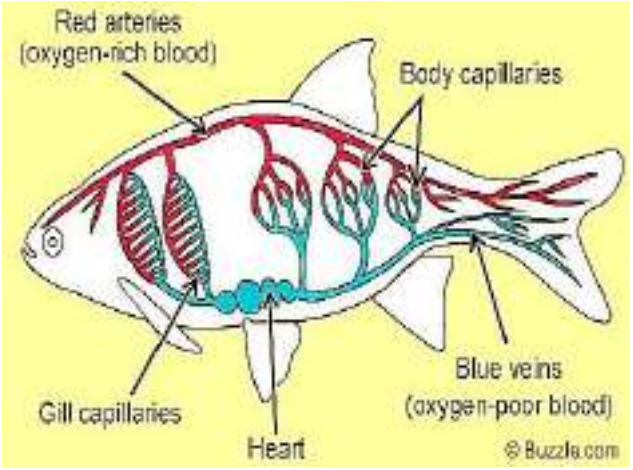
Insect blood has no haemoglobin therefore, it's not red on colour. It has greenish-yellow blood which contains nutrients and body wastes, but no oxygen.

Transport in Vertebrates

- Vertebrates' animals are generally larger and more active than invertebrates so they need more efficient transport systems.
- All vertebrates have a closed circulatory system with a chambered heart to pump blood.

Transport in Fish (closed, single – loop circulation)

- Fish have the simplest circulation system with two chambers – one auricle and one ventricle.
- The heart pumps the blood in only one loop, from ventricle to gills to body cells back to the heart.
- A fish heart does not have to pump as hard like in land animal because water reduces the force of gravity.
- Fish blood can make it through the gills and the body without returning to the heart for a second push.

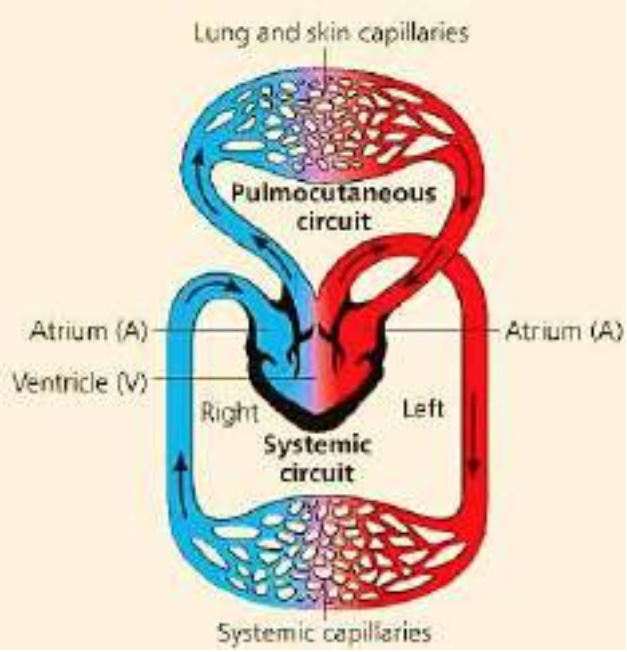


Source: *http://www.buzzle.com/*

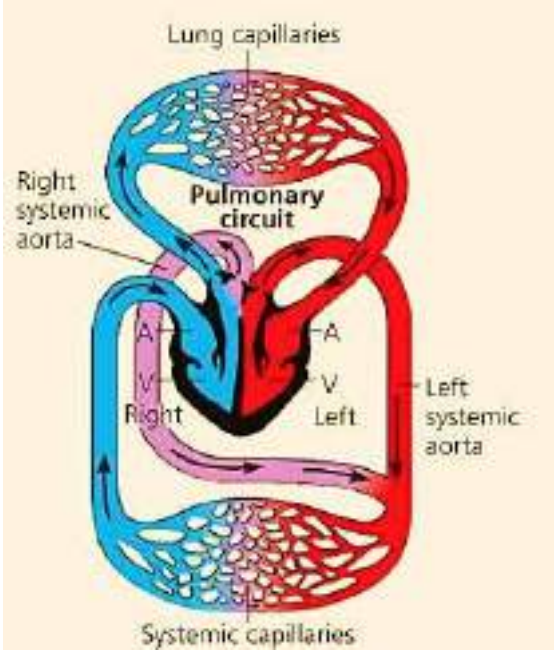
Transport in Amphibians and Reptiles - Closed, partial double-loop circulation.

- Amphibians (toads) and reptiles (snakes, lizards, etc) both have three- chambered heart with two auricles and one ventricle.
- They have a closed partial double loop circulatory system.
- A single ventricle pumps oxygenated blood to the body and deoxygenated blood to the lungs.
- This circulation is only a partial double loop because the two loops overlap.
- Oxygenated and deoxygenated bloods mix in the ventricle.

Amphibians



Reptiles



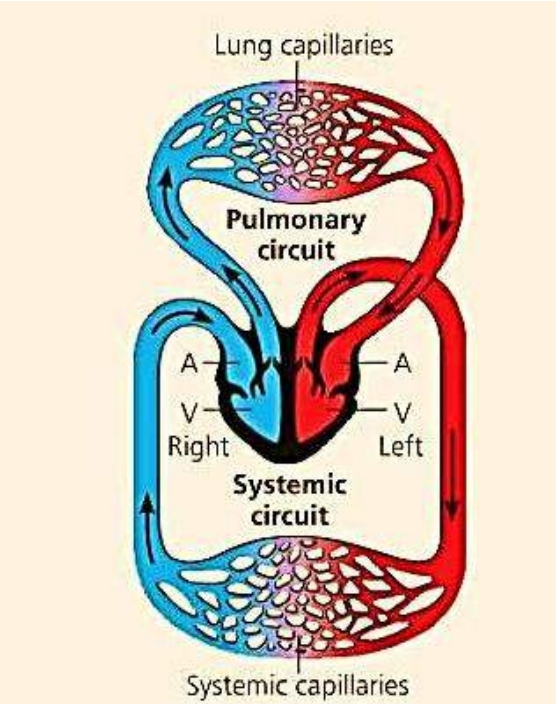
Adaptive Value

- In amphibians and reptiles, oxygenated and deoxygenated blood mix in the single ventricle. Some of the blood that the heart pumps to the lungs is already oxygenated. Some it pumps to the body is deoxygenated.
- Since amphibians and reptiles are cold- blooded and generally less active than birds and mammals, they can manage with less efficient blood circulation.
- Additionally, most reptiles have at least a partial wall in their ventricle to separate the oxygenated and deoxygenated blood. This increases the efficiency of their transport system.

Transport in Mammals and Birds - Closed, double-loop circulation

- Mammals and birds have four-chambered hearts – two auricles and two ventricles.
- Their blood circulates in two loops.
- One loop is between the heart and the lungs.
- The other is between the heart and the rest of the body.

Mammals and Birds



Adaptive Value

- Mammals and birds have the most efficient transport system of all organisms.
- Their deoxygenated and oxygenated blood is completely separated into the right and left sides of the heart.
- The heart pumps blood to the body forcefully since blood returns to the heart for a second push after it passes through the lungs.
- Mammals and birds need efficient transport for:

1) **They are warm blooded.**
2) **They are very active.**
3) **Flight in particular consumes energy very quickly.**

- ❖ Some mammals, such as whales and elephants, are very large. Without an efficient transport system, they would not be able to supply their cells with enough oxygen to survive.
- ❖ Bird and mammal brains have a more developed cerebrum than most animals. The cerebrum consumes large amount of oxygen and nutrients.

Warm – blooded versus Cold – blooded

- Mammals and birds are warm-blooded.
- They keep their body temperatures constant regardless of environmental temperature.
- For e.g., humans keep their body temperature at 37°C, regardless of the temperature of the environment they are in.
- Normally air temperature is lower than the body temperature of birds and mammals.
- Therefore, these animals constantly lose heat to the air.
- Keeping the body warm in spite of constant heat loss requires plenty of energy.
- This is why warm-blooded animals need a very efficient oxygen and nutrient supply.
- All other animals, including fish, amphibians and reptiles, are cold-blooded.
- Their body temperatures vary with the environmental temperature.
- Cold- blooded animals consume less energy than warm- blooded animals.
- However, when the air is cold they cannot be very active because their metabolic reactions are too slow (the rates of virtually all reactions increases as temperature increases).

ADAPTATIONS FOR TRANSPORT

- ❖ All cells need a constant supply of nutrients and oxygen and removal of metabolic wastes.
- ❖ Direct diffusion is suitable for that have large surface area - area to volume ratios.
- ❖ Larger, active organisms need a special transport system to carry materials to and from their cells.
- ❖ The transport system of larger animals may interact with the following systems:

  - ✓ The **digestive system** to get nutrients.
  - ✓ The **respiratory system** to exchange gases.
  - ✓ The **excretory system** to remove nitrogenous wastes and excess salts.

Transport Method	*Organism*	*Adaptive Value*
Direct Diffusion	- bacteria - fungi - protists - cnidarians	no separate transport system, materials diffuse directly to and from cells; supplies enough materials and carries wastes away fast enough to support small or sessile organisms
Open Circulation	- arthropods - molluscs	blood is pumped by a heartbeat into an open body cavity, it is not contained in vessels; sufficient for small organisms which have a separate system that provides cells with oxygen
Closed Circulation	- annelids - vertebrates	blood does not directly touch cells, it is contained in vessels; needed in active, larger organisms to adjust blood flow to different body parts and to supply materials and remove wastes quickly.
Single – loop Circulation	- fish	blood passes through the heart only once (blood from the gills does not return for a second push before going to the rest of the body cells.); blood can make it through the gills and the rest of the body because being under water reduces the effect of gravity.
Partial double-loop Circulation	- reptiles - amphibians	blood passes through the heart twice but mixes in the single ventricle; blood gets the extra push it needs to flow against gravity in land animals
Double loop Circulation	- birds - mammals	blood passes through the heart twice, oxygenated and deoxygenated blood do not mix; this is the most efficient transport system of all.

SELF TEST

1. Transport systems often link with the following systems: digestive, gas exchange, and urinary. Explain the reasons for each of these connections.

2. What three factors are believed to help water move up through xylem? Describe how each force works.

3. How do plants absorb water from the soil? How do they absorb minerals?

4. Describe how food is transported in vascular plants.

5. What two kinds of cells make up phloem? What is the function of each?

6. Describe how xylem cells and sieve cells are specially adapted for their functions.

7. What is the difference between open and closed circulation? Give an example of an organism with each kind of circulation.

8. Why don't large organisms have open circulation?

9. Write out the path of blood flow in hornet, an earthworm, a fish, a toad and a bulbul. For each choose the words that apply from the following list: left ventricle, right ventricle, right auricle, left auricle, ventricle, auricle, simple heart, haemocoele, vessels near body cells, vessels in gills, vessels in lungs, heart-like vessel, Ostia.

10. In animals with closed circulation, the blood does not actually touch the animal's cells. How do the materials move between the cells and the blood?

11. What is the difference between single-loop and double loop circulation? Is circulation in these loops closed or open?

12. State how many chambers the heart of each of the following animals has: a frog, a mynah, a dog, a fish.

13. In spite of having only single loop circulation, a fish's circulatory system is able to supply cell nearly as quickly as the double-loop circulatory system of a mammal. Why?

14. Define the words cold-blooded and warm-blooded and give example of an animal with each.

15. State one advantage and one disadvantage of being cold-blooded.

16. Which is more efficient, a three-chambered or four-chambered heart? Why?

17. Why must birds sit on their eggs while other egg-laying animals, such as fish and mosquitoes, do not?

18. Compare the transport system in an annelid and in a fish.

BI 12.1.4.4 EXCRETION AND OSMOREGULATION

Homeostasis means to maintain a constant stable internal environment/condition. Some common homeostasis processes in organisms to maintain stable environment includes:

(1) Regulation of blood pH.
(2) Regulation of blood sugar level. Mammals use insulin and glucagon.
(3) Regulation of excess water and ions by kidneys and liver in vertebrates.
(4) Regulation of constant body temperature in warm-blooded animals.
(5) Regulation of oxygen content in blood.
(6) Regulation of water content in blood and lymph fluid.

The two processes which play an essential role in homeostasis are: (1) Excretion and (2) Osmoregulation.

To prevent osmotic problems, organisms excrete waste products of their metabolic reactions and regulate the balance of solutes and water in extracellular fluid.

Excretion

- **Excretion** is the process of removing **metabolic waste** products from the body.
- Excretion is **different** from **egestion**. **Egestion** is removal of **undigested waste** material from the body via alimentary canal (Example: Faeces).
- Metabolic waste products can be harmful to the organisms and therefore needs to be excreted (removed) from the body.
- Carbon dioxide from respiration and nitrogenous wastes from deamination of amino acids are two major metabolic wastes.
- Carbon dioxide is excreted from the body via exhaling and nitrogenous waste is excreted by kidneys.
- Some small sessile organisms have the ability to diffuse the metabolic wastes out of their body directly but for larger active organisms which produce more metabolic waste, special systems and organs are in place to excretion.
- Every species has a waste-removal system suitable for its lifestyle and environment.

Osmoregulation

- Osmoregulation is the process of maintaining the solute concentrations constant in the fluid in and around cells to avoid it from becoming excessively flaccid or turgid.
- Too much or too little of any solute can kill an organism.
- Excretion intertwines closely with osmoregulation as it gets rid both water and solutes.
- For terrestrial organisms, osmoregulation requires adaptations for water conservation.

PLANTS: EXCRETION AND OSMOREGULATION

- Plants use most of the waste products they produce, including CO_2, O_2 and ammonia.
- CO_2 is used in photosynthesis; O_2 for plant respiration and ammonia for nitrogen.
- Those gases which are not immediately required by the plant for photosynthesis or respiration are diffused out.
- While plants do not have to worry much about excretion, most land plants face the constant threat of dehydration.

Water Conservation in Terrestrial Plants

- Water is needed by plants for two things: (1) photosynthesis and (2) maintaining cell turgidity.
- Terrestrial plants need transpiration to pull water up from their roots and to cool their leaves.
- Plants lose about 90% their water intake by transpiration through open stomata.
- If a plant loses more water than it absorbs, it will wilt and eventually die.

Adaptations of Plants to Reduce Water Loss

- **Waxy Cuticle**- covers stems and the top surface of leaves to prevent water evaporation.
- **Stomata**- present mainly on the bottom-side of the leaves in order to reduce transpiration.
- **Guard Cells**- closes stomata at night and whenever the plant does not have enough water.
- **Adjustment of Leaf Angle**- in order to reduce the amount of the leaf surface exposed to sunlight, some plants can adjust the angle of their leaves leaf sun on the leaves when excess water is being lost via transpiration.

Stomata & Guard Cells

When guard cells are:

- Turgid- stomata opens
- Flaccid- stomata closes

Additional Water Loss Adaptations

Some plants have the ability to survive in very dry environments. Some additional adaptations which they have to conserve water are:

- **Succulence**–plants store water in fleshy leaves, stems or roots in gel-like compounds and cells from which it is not easily lost. Example: cactus and aloe vera.
- **Thick Cuticle**- reduces water loss via transpiration.
- **CAM Plants**- these plants open stomata at night to capture CO_2 and during the day they keep the stomata closed but continue to photosynthesize.
- **Protection Structures/compounds**–stored water is protected from thirsty animals using spines, bitterness and needle-like structures.
- **Drought dormancy** – some desert plants withstand desiccation in drought periods by appearing dead or near-dying but will flourish back again once there is rain. Some plants also drop off all the leaves to reduce transpiration.

PLANTS: EXCRETION AND OSMOREGULATION

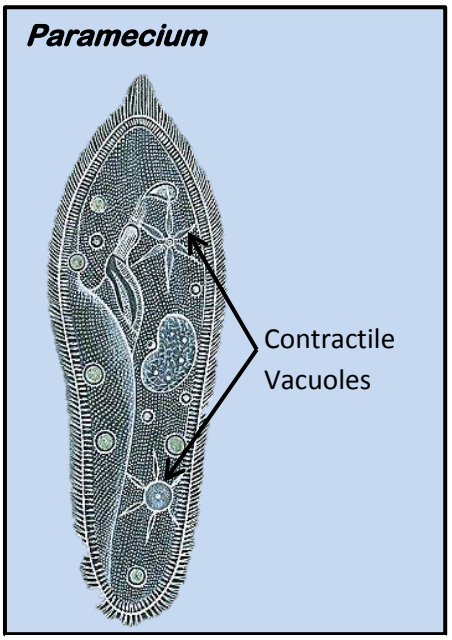
- Plants excrete some waste through diffusion.
- During the day, excess oxygen gas produced by photosynthesis is released through the stomata.
- Carbon dioxide produced by respiration is normally used up during photosynthesis. At night, carbon dioxide is not used up as fast as it is produced and is released as a waste product.
- Plants also eliminate waste by **abscission** where the waste is accumulated in the vacuoles of the aging leaf cells which eventually die and fall off, removing waste in the process.
- The sticky, milky or oily substances (resins, gums, latex) that ooze from the bark of trees are excretory products.
- Osmoregulation in plants is mainly maintained by the stomata.

PROTISTS: EXCRETION AND OSMOREGULATION

- Unicellular protists do not have to invest into large systems for excretion and osmoregulation.
- They rely on simple diffusions to get rid of their metabolic wastes.
- Note: Not all protists are unicellular there are some multicellular protists also.
- Protists living in fresh water face a lot of osmotic problems since water constantly moves into their body cells. To encounter this problem, such protists have special cell organelles and/or mechanism in place to remove excess water.

Osmoregulation in *Paramecium*

- *Paramecium* is a genus of unicellular freshwater protists.
- The solute concentration in the *Paramecium's* cell cytoplasm is higher than in the fresh water outside the body/cell. Thus, water moves in by osmosis, causing the cell to swell.
- In order to maintain solute balance, all *Paramecium* have special cell organelles called **contractile vacuoles** that actively take in excess water and squeeze it back out of the cells.
- Contractile vacuoles pump water out of the body to maintain a stable solute and water concentration inside the cell cytoplasm.
- If the contractile vacuoles stop working, the *Paramecium's* cell will fill up with water and eventually burst.



Source: *www.suggestkeyword.com*

- Since contractile vacuoles are squeezing water out against the concentration gradient, it requires energy and therefore mitochondria is usually located near the contractile vacuoles.
- When mitochondria produce energy via respiration process, it produces CO_2. This CO_2 is excreted by diffusion and also by contractile vacuole along with water.

ANIMALS: EXCRETION AND OSMOREGULATION

- Excretion and osmoregulation in animals depends on its lifestyle and environment.
- Excretion in aquatic animals is easy since poisonous ammonia wastes are readily diluted with plenty of water.
- Osmoregulation is a problem for aquatic animals due to osmosis. Water moves into freshwater animals and out of saltwater animals.
- On the other hand, excretion can be a problem for terrestrial animals since they must also conserve water.
- Terrestrial animals constantly lose water by:
  - Excretion of urine;
  - Evaporation from the skin and respiratory surfaces;
  - Elimination of water by drinking, eating food that contains water; and
  - Producing metabolic water by the respiration reaction.

Nitrogenous wastes result from the breakdown of excess amino acids. Most of an amino acid molecule can be used for energy, but the nitrogen part is waste.
The three types of nitrogen –containing wastes are:

1. **Ammonia -** the original product of deamination: very toxic (poisonous) so it must be diluted with plenty of water e.g. aquatic animals- Fish, tadpoles
2. **Urea-** made form ammonia, not as toxic as ammonia e.g. terrestrial mammals
3. **Uric acid** – insoluble nitrogen waste crystal, not toxic e.g insects and reptiles.

Excretion and Osmoregulation in Invertebrate Animals

I. Aquatic Invertebrates: Cnidarians and Mollusc (Bivalves)

Excretion and Osmoregulation

- Sessile aquatic animals in which ammonia diffuses out into the surrounding water.
- These organisms are small and create metabolic wastes slowly. Therefore, they do not need a special excretory system.

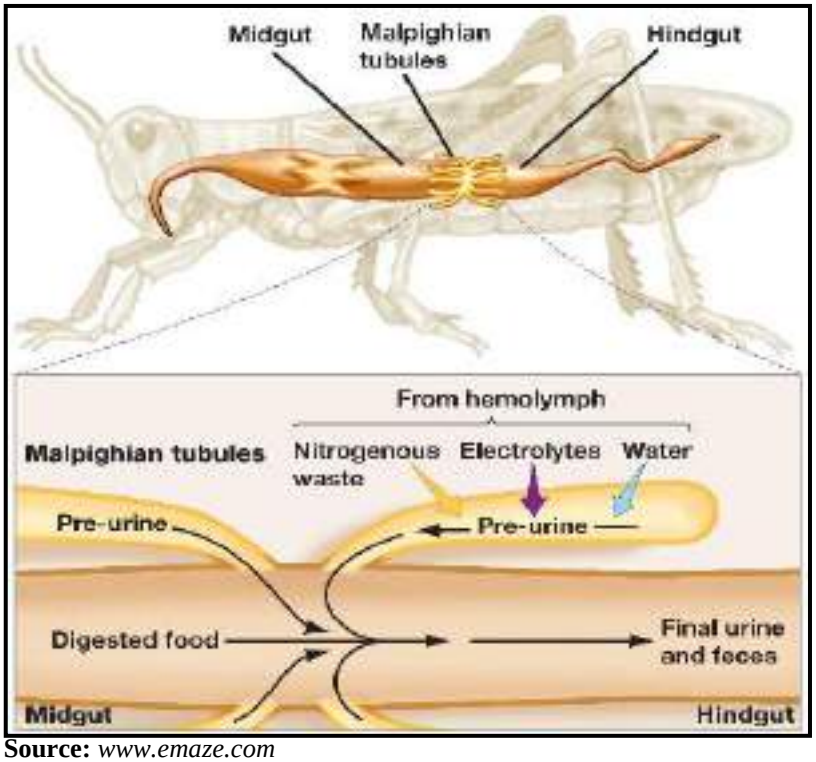
Water Conservation

- They live in water; therefore do not worry about dehydration.

II. Terrestrial Invertebrates: Insects

Excretion

- Excretory organ of the insects are known as **Malpighian Tubules**. These are tube extensions of the gut which float in the open blood cavity (haemocoele).
- Excretory products of insects are **uric acid**. The Malpighian tubules absorb nitrogenous wastes form the blood and convert it to **uric acid**.
- The tubules join with the hind gut and uric acid crystals pass out with the faeces.



Source: *www.emaze.com*

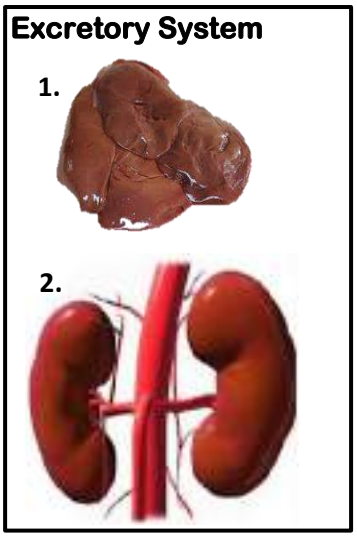
Water Conservation

- ❖ Insects are terrestrial animals which face the constant threat of dehydration. Their water conserving adaptations include:
- Excretion of solid uric acid crystals instead of urea which needs to be diluted in water.
- Waxy exoskeletons reduce water evaporation form body surfaces.
- The moist respiratory surfaces of the trachea are inside their bodies in order to reduce evaporation.
- Closing of spiracles when they are inactive.
- The hind gut reabsorbs water from the faeces.

Excretion and Osmoregulation in Vertebrate Animals

- ❖ All vertebrates share similar excretory systems which include:
  (1) **Liver**- which deaminates excess amino acids; and
  (2) **Pair of kidneys**- which filter the resulting nitrogenous wastes out of the blood.

- ❖ Using hormones, the brain tells the kidneys how much water and salts the body needs to retain to maintain homeostasis.



Source 1:*www.eatmedaily.com*
Source 2:*www.clinicalstudies.com.au*

I. Aquatic Vertebrates: Fish

Excretion and Osmoregulation

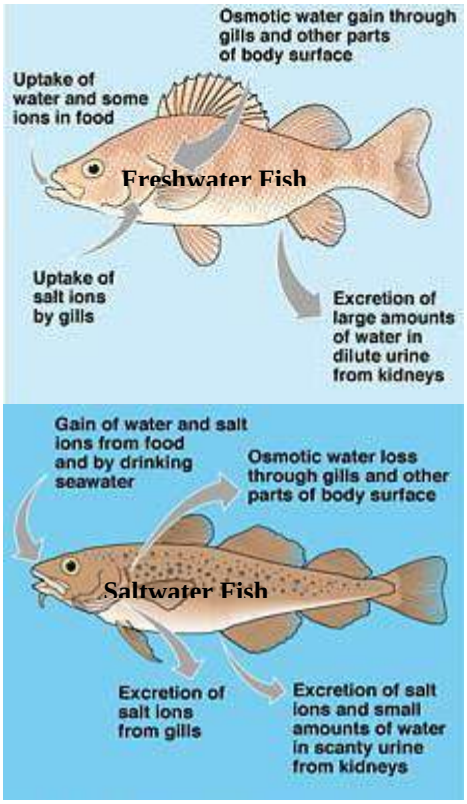
- Both fresh and saltwater fish excrete ammonia directly into water therefore no energy is spent on converting it to urea.
- However, fish face osmotic problems. Water constantly moves into freshwater fish's cells and move out of a saltwater fish's cells.

Freshwater Fish

- The solute concentration in the cells of a freshwater fish is higher than that of the surrounding water and therefore water constantly moves into the fish's gill cells and the fish loses a lot of salts.
- They maintain water balance by constantly excreting large amounts of very dilute urine.
- Freshwater fish replaces salts by actively absorbing them from surrounding water through special cells in their gills.

Saltwater Fish

- The salt water surrounding ocean fish has a higher solute concentration than that inside fish cells.
- Thus saltwater fish constantly lose water by osmosis.
- To solve this problem, ocean fish constantly drink salt water and then excrete excess salt through special cells in their gills.



Source: *www.pleasanton.k12.ca.us*

II. Terrestrial Vertebrates:

1. Amphibians (Example: Frog)

Excretion, Osmoregulation and Water Conservation

- Adult life spent on land but the body not well adapted for conserving water.
- Amphibians partly breathe through their skin and therefore the skin needs to be moist for gases to dissolve and diffuse.
- Since breathing takes place via skin; the skin lacks additional protective coverings.
- Amphibians excrete urea which requires dilution with water.
- Since amphibians spent juvenile (young) part of their lives in water, finding moist habitats are easy for them.

2. Reptiles (Example: Gecko/Lizard; Turtles)

- Well adapted for conserving water.
- Ability to excrete **solid uric acid crystals** (also known as: urates) and **urea**.
- Excreted uric acid is white in colour while urine is colourless.
- To conserve water, reptiles have scales covering their skin and exchanging of gases uses lungs. Lungs are inside their bodies to reduce evaporation from moist respiratory surfaces.

The droppings of house lizard and birds are mostly white and black/brown. The white part is the uric acid crystals and the brown part is faeces (undigested food).

3. Birds

- Also excrete uric acid.
- To prevent dehydration:
  - Feathers cover the body.
  - Scales on legs (where there is no feathers)
  - Gas exchange via lungs which is kept moist inside the body.

4. Mammals

- Excrete urea diluted in water.
- To replace the amount of water lost urine, by evaporation and by exhalation, most mammals must drink water quite regularly.
- The feeling of thirst caused by hormones is an adaptation to remind the mammal to rehydrate.
- Humans require plenty of drinking water since they lack heavy fur to prevent evaporation from skin.
- On the other hand, some dessert mammals (Example: Camels) are well adapted for water conservation since they manage to survive only on the water they derive from respiration and food.
- Osmoregulation in kidneys occurs at **loop of Henle**. Here, most of the body fluids and essential nutrients are reabsorbed. Most of the water is also reabsorbed from the undigested food in the large intestine.
- Osmoregulation is also maintained by the anti-diuretic hormones (ADH). The water level in the blood needs to be constant to avoid cell damage and therefore when the body is dehydrated, this hormone release by the pituitary gland. It travels in the blood to the kidneys where it affects the tubules so more water is reabsorbed into your blood. Hence, lesser volume of more concentrated urine is produced. The level of water in your blood increases until it is back to normal.

Advantages of Excreting Uric Acid

(Insects, Reptiles and Birds)

1. Reduces water loss since it does not require dilution.
2. Solid uric acid is lighter than liquid urine - aids in flight since it does not add extra weight.
3. Embryos developing in eggs do not poison themselves with their own wastes since uric acid is harmless compared to if they excreted urea or ammonia.

SUMMARY TABLE		
Method of Excretion and Osmoregulation	**Organisms**	**Adaptive Value**
Direct Diffusion No excretory system, wastes simply diffuses out.	Plants, bacteria, some protists, fungi, cnidarians, some molluscs	▪ Sufficient for sessile organisms. ▪ Energy not spent/ wasted.
Contractile Vacuoles Cell organelle which absorbs excess water and pumps it out of the cell.	Freshwater protists	▪ Removes water that constantly moves into the cell by osmosis.
Malpighian tubules Tube extensions of the gut which float in the haemocoele	Insects	▪ Absorbs uric acid from the haemocoele. ▪ Light-weight excretory product- aids in flight. ▪ Not poisonous to the organism. ▪ No dilution required.
Kidneys and Liver	Vertebrates	▪ Very efficient blood filtering. ▪ Precise control of the body's water\solute concentration.

Evolutionary Trends

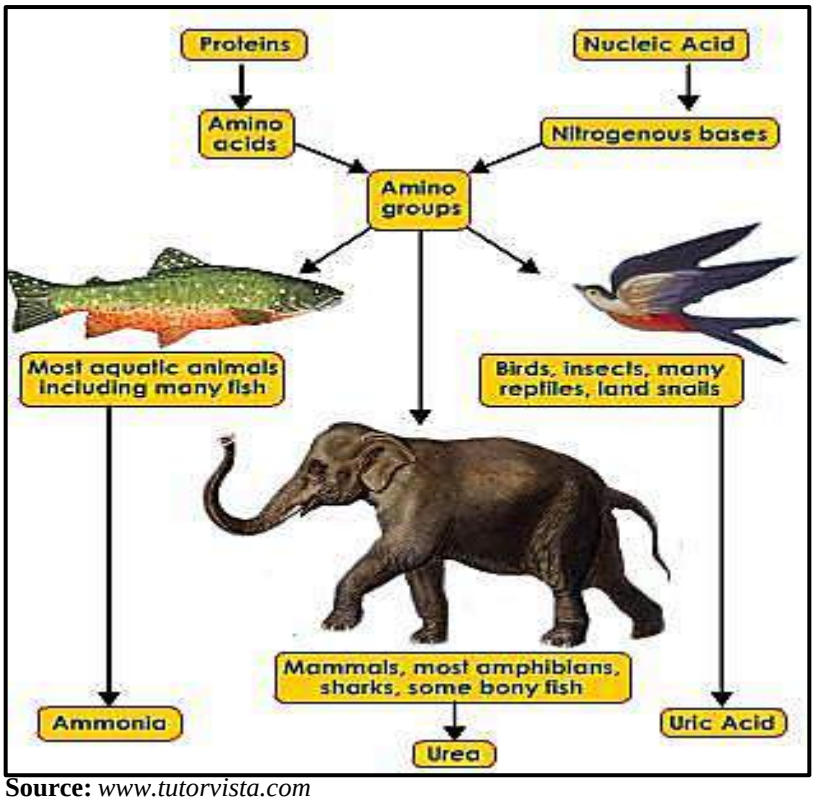
Excretion varies greatly between invertebrates and vertebrates, depending on the complexity of the organism.

Excretion in invertebrates varies from protozoa that are by diffusion through the membrane, the Porifera from cells that specialize in this function, and arthropods which have specialized excretory organs- malpighian tubes.

Excretion in vertebrates is characterized by the presence of an excretory organ located mostly in dorsal, posterior end of the vertebrae, which are called the kidneys.

In the kidneys are capable of excreting waste in various forms as outlined in the diagram below.

Excretory systems of Vertebrates



Source: *www.tutorvista.com*

SELF TEST

1. Explain the difference between osmoregulation and excretion.

2. How is homeostasis different from excretion and osmoregulation?

3. Identify the function of the liver as part of the excretory system in vertebrates.

4. Name three nitrogenous waste products produced by animals.

5. Identify some water conservation adaptations of terrestrial plants.

6. Identify four ways in which insects reduce water loss.

7. Briefly explain how human excretory system (liver and a pair of kidney) conduct excretion and maintain osmoregulation.

8. Correct the sentences below to make it true:

Marine fish continually gain water through osmosis. In order to maintain osmotic balance of its body cells with the surrounding water, such fish drink water continuously drink water and excrete very concentrated urine from liver.

9. Identify the advantages and disadvantages of the excreting the following products:

Waste	Advantages	Disadvantages
Ammonia		
Uric Acid		
Urea		

10. What is the advantage of excreting uric acid rather than urea in the egg-laying terrestrial reptiles and birds?

11. Identify the major disadvantage that fish would face if it instead of excreting ammonia it converted and excreted urea.

12. Compare excretion of a jellyfish with that of a terrestrial mammal. Explain with reference to their lifestyle, the adaptive value of the excretory method to them.

13. Name the structure that maintains osmoregulation in freshwater *Paramecium* and explain the significance of many mitochondria surrounding this structure. Would the seawater/ marine *Paramecium* also have the same cell organelle to maintain osmoregulation? Explain your answer.

14. Briefly outline how homeostasis ensures a constant body temperature and blood sugar levels in humans. You may refer to internet sources and reference textbooks to answer this question.

BI 12.1.4.5 PROTECTION, SUPPORT AND MOVEMENT

Organisms possess certain structures and/or adaptive features which provide them with some form of protection, support, and movement to successfully exploit their environment.

The adaptive structures often include those that provide **protection** from dehydration, disease and predators; **support** against gravity; and **movement** for finding food and escaping predators.

Organism's means of protection, support and movement are suited to its way of life.

Example

Centipedes have poisonous bites which they use to defend themselves, their food and their habitat. Land plants have the shiny waxy cuticles to reduce transpiration. Tall trees have heartwood and lignin to strengthen their stems. Birds and bats have extremely light-weight bodies and broad wings.

Factors Affecting Protection, Support and Movement

- **Aquatic and Terrestrial Habitat**- organisms dwelling in aquatic habitats have totally different requirements in terms of support, movement and protection from the organisms that dwell in terrestrial habitats due to the nature of the environment that they are exposed to.

Aquatic Organisms (Water)	Terrestrial Organisms (Land)
➢ No need to protect itself from dehydration since it lives in water	➢ Needs to protect itself from dehydration
➢ In the water, the pull of gravity experienced by the organism is reduced due to the buoyant force in the opposite direction.	➢ Requires stronger support system to cater for the strong gravitational pull that is experienced by the body.
➢ Movement in water requires different structures to aid in movement (example, fins in fish to swim)	➢ Movement on land requires different structures (example, skeletal structure made of bones)

PLANTS: PROTECTION, SUPPORT AND MOVEMENT

Movement in Plants

- Plants do move but since they make their own food, they have limited movement capabilities.
- Plant movements are not extensive because they do not have to travel from one place to another in search of food.

- Some lower group of plants (algae) show locomotion with the help of cilia but the higher plants can only exhibit change in position of the organs.
- The major types of movement in plants are: (1) Tropic and (2) Nastic movements.
- Since tropic movements (tropisms) have been extensively studied before; we will only concentrate on nastic movements.

Nastic Movement

- Movement due to changes in turgor or changes in growth.
- These movements are non-directional.

- **Nyctinasty**- movement in plant organ in response to the onset of darkness. Also known as 'sleep movement'.
  Example: many leguminous close leaflets at night and also the '*vaivai'* or '*mocemoce'* plants.

- **Photonasty**- movement of plant organs in response to light.
  Example: opening and closing of flowers.

- **Chemonasty**- movement of plant organs in response to chemical/nutrients.
  Example: Dragon fly and Venus fly trap.

- **Thigmonasty**- movement of plant organs in response to vibration or touch.
  Example: Sensitive grass

Examples of Plants that Move

Plants that Move to Capture and Consume Prey

Sundew

Source: *www.growsundews.com*

Venus Fly Trap

Source: *www.vishub.org*

Waterwheel

Source: *www.sarracenia.com*

Plants that Move Leaves

Sensitive Grass

Source: *www.etsy.com*

Partridge Pea

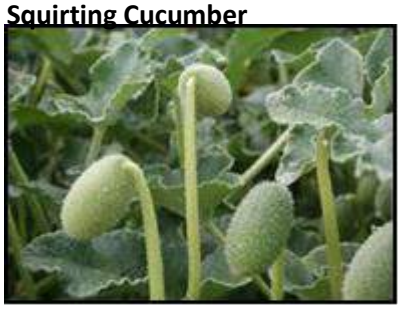
Source: *www.grownative.org*

Yellow Neptunia

Source: *www.stevenfoster.com*

Plants that Spread Seeds or Pollens by Rapid Explosion

Squirting Cucumber



Source: *www.crete-birding.co.uk*

Resurrection Plant

Source: *www.quantumbiologist.com*

Resurrection Plants displays remarkable ability to survive near desiccation causing it to appear nearly dead but when rehydrated these plants are revived.

Protection in Plants

Protection in Plants- From being Eaten, Pulled and/or Torn

- In order for the plants to protect their stored food for later use in growth and reproduction, they have certain adaptive features which prevent the consumers (herbivores and omnivores) from eating it.
- Ways in which plants protect themselves can be categorised into three groups: (1) Structural Defence; (2) Chemical Defence; (3) Behavioural Defence.
- Some such adaptive features of the plants which provide protection from being eaten are:

1. Thorns and Spines (Structural Defence)

Rose Plant

Lemon Tree

Cacti

2. Poisonous Leaves(Chemical Defence)

(Note: These leaves are not poisonous to all organisms but some specific ones)

Neem Leaves

Lanatana

Mother-in-laws Tongue

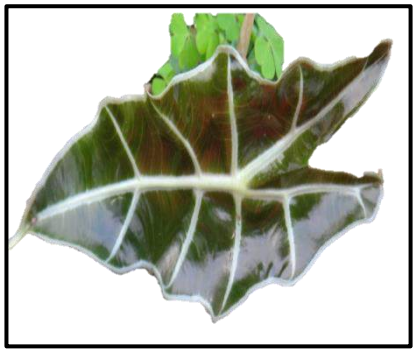
3. Hairy Leaves and Stems (Structural Defence)

Tomato leaves and stem

Eggplant leaves

Pumpkin Leaves

4. Thick Leaf Cuticles



5. Sharp Leaf Edges (Structural Defence)

Coriander family

Coconut Leaves

Conifers

6. Bad Smell (Chemical Defence)

Western Skunk Cabbage

Dead Horse Arum Lily

Corpse Flower

Source: *http://listcrux.com/top-10-flowers-that-smell-real-bad/*

7. Bark (Structural Defence)

8. Sensitive Grass (Behavioural Defence)

Source: *www.gardenrant.com*

- Investing in adaptive features for protection uses up a lot of energy and therefore some plants do not invest in any special defence mechanism against herbivores and omnivores.
- As a form of protection, such plants only have an epidermis and cuticle and therefore produce enough food to survive even when some is consumed.
- Plant's cuticle and epidermis not only protects against it being eaten but also helps protect against diseases just as our skin does.
- Bark on trees provides additional protection.

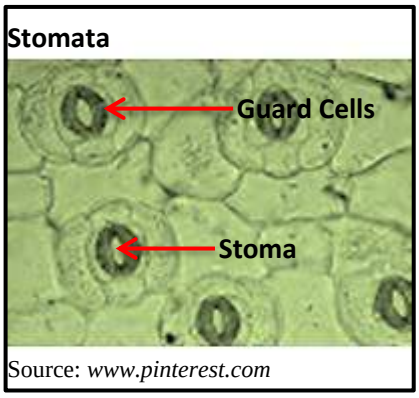
Protection in Plants- From Dehydration/ Desiccation

- Just as we perspire (sweat) to cool our skin so does the plants via the process of transpiration.
- Transpiration is the movement of water through the plant and its evaporation from the aerial (top) parts especially through the leaves.
- When water is drawn up from the roots and lost through the leaves via stomata, the plant gets cooled.
- However, when there is limited water available as in the case of prolonged dry seasons and droughts, plants choose to close their stomata.

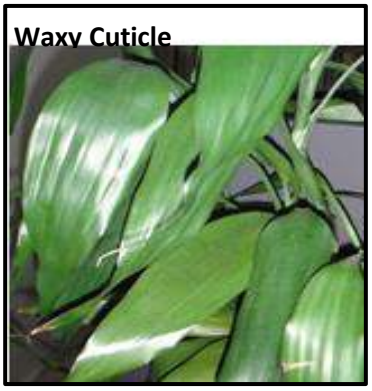
- The adaptive features of **land plants** which protect from desiccation are:
  (1) More stomata is present on the lower surface of the leaf than on the upper surface
  (2) Stomata have guard cells which open and close the stomata as per need.
  (3) Waxy cuticle on the upper surface of the leaves reduces the water loss via transpiration from the top surface.
  (4) Presence of tiny hair-like structures on the leaves also helps reduce transpiration.

Interested in Seeing Stomata!!!

1. Take a leaf
2. On the underside of the leaf, paint a small section with clear nail polish (keep the nail polish layer thin)
3. Dry the nail polish
4. Stick a clear cello-tape on the dried nail polish.
5. Pull out the cello-tape from the leaf and stick it onto a clean glass slide.
6. Observe the slide under a microscope.



Source: *www.pinterest.com*



Aquatic Plants

Aquatic plants do not have to conserve water and therefore have different adaptive features and mechanisms from the land plants.

- Some aquatic plants, especially the floating plants lack guard cells on the stomata and some do not have any stomata at all (submerged plants).
- For the floating plants, the stomata are present on the upper surface of the leaves to enable exchange gases with the air.
- Mostly the submerged plants lack waxy cuticles or have a very thin layer of the waxy cuticle to aid in efficient gas exchange while some floating aquatic plants have the thick waxy layer to repel water and keep the stomata clear.

Water Lily

Source: *www.wisegeek.org*

Support in Plants

- The main role of the plants as producers is to photosynthesise. In order to do carry out this role effectively, plants need mechanisms which enable them to gather the key ingredients required for photosynthesis.
- The key ingredients required for photosynthesis are: water, carbon dioxide and sunlight.
- Carbon dioxide is easy to obtain because it is present in the air. However, obtaining sufficient amount of sunlight and water pose some problems for plants.

Support in Plants to Acquire Adequate Sunlight

In order to maximise the amount of the sunlight received, many plants grow upwards and outwards. However, the taller a plants grows the more support it needs against gravity.

Support in Herbaceous Plants

- Herbaceous plants are "soft-stemmed" plants such as herbs and other small plants.
- Herbaceous plants do not live for long.

- These plants mostly don't grow tall and therefore not very strong methods of support needed.
- Those herbaceous plants that grow tall (eg. Balabala and banana) fall down easily.

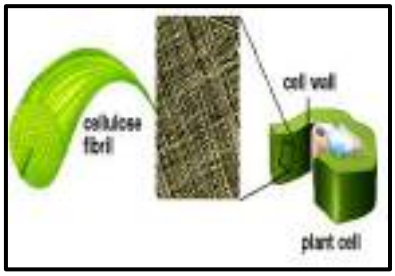
- These plants support themselves in three ways:

1. **Cellulose in plant cell walls –** cellulose is a tough carbohydrate that makes plants cell walls rigid.

2. **Turgor Pressure** –pressure created when fluid is tightly filled in each cell. In presence of sufficient water, the cells remain turgid. When plants lose too much water, the cells become flaccid (limp) from water loss and wilts.

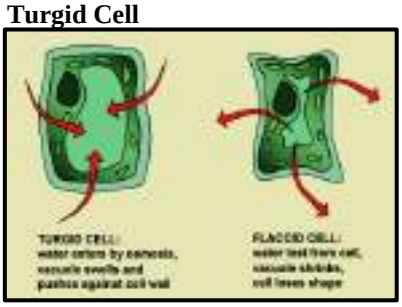
3. **Cortex tissue –** cortex cells are the unspecialised cells lying between the epidermis and the vascular tissues. These cells and other strong fibrous cell tissues is the major component in plants stems and roots. Cortex cells also store starch.

Cellulose



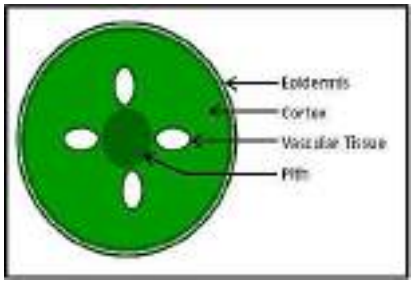
Source: *McGraw-Hill Companies*

Turgid Cell



Source: *visualvocabulary.blogspot.com*

Cortex Tissue



Other Adaptations for Support in Herbaceous Plants

- Some herbaceous plants grow tall without investing much in its own support mechanisms.
- Examples of such plants are epiphytes and climbers.

- **Epiphytes** root themselves in the tall plants instead of soil to receive adequate sunlight. The host plants are not negatively affected by the epiphytes. Some examples of epiphytes are:

- **Climbers** root themselves in the soil but climb upon tall plants and other support structures such as sticks etc.
- In order to climb other support structures, climbers invest in structures such as tendrils, spines or wrap. Climbers are often stuck in the shade of their host plant.
- Some examples of climbers are: bean plants, bougainvillea, yam plants, pumpkin plants

Tendrils - small cucumber (gherkins)

Support in Woody Plants

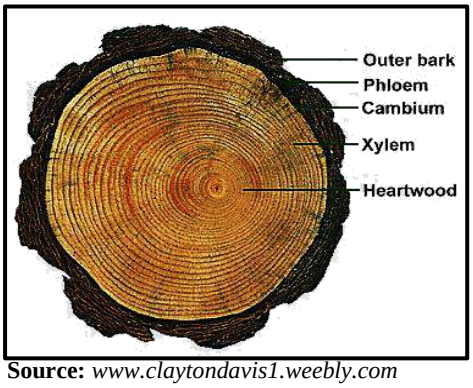
- ❖ Woody plants have evolved strong support mechanisms to enable them to grow tall without using other plants as support.
- ❖ These plants live for long and therefore they make big investments in their support mechanisms.
- ❖ In addition to cellulose and turgor pressure, woody plants have:

1. **Lignin**- a very strong carbohydrate that strengthens cell walls.
2. **Heartwood-** dead xylem at the centre of the stem which has filled with hardened sap.
3. **Root System-** which is deep and extensive to anchor the plants in the ground.

Interesting Facts:

- **Tallest Plant**
  Name: Hyperion
  Height: ≈ 116 m
- **Oldest Plant**
  Name: Pine species
  Age: ≈ 5064 years

Heartwood



Source: *www.claytondavis1.weebly.com*

Root System

Source: *www.123rf.com*

SUMMARY TABLE FOR PLANTS

	Herbaceous Plants			Woody Plants
	Normal	**Epiphytes**	**Climbers**	
Example	Plants: pawpaw, balabala, hibiscus	Orchids; some ferns	Mile-a-minute	Trees: Dakua, Mahogany,
Movement	Limited movement for pollination etc. It is not <u>motile</u> (Moving or having the power to move spontaneously)			
Protection against predation	• Thorns and spines • Poisonous or sharp leaves • Bad smell • Leaves with thick cuticle • Barks • Woody plants grow tall			
Protection against Desiccation (terrestrial)	• More stomata on lower surface than on upper surface • Waxy cuticle on upper surface • Guard cells to close the stomata • Tiny hair-like structures on the leaves to reduce transpiration			
Support	• Cellulose • Turgor pressure • Cortex tissues	• Strong thick roots • Small size	• Tendrils • Twining- stems that can bend, twist and coil • Adventitious roots	• Heartwood • Lignin • Extensive root system

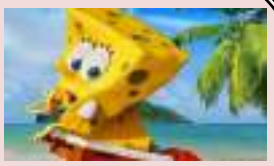
ANIMALS: PROTECTION, SUPPORT AND MOVEMENT

Movement, Support and Protection

- Not all animals can move, some are sessile (can't move).
- Those animals that can move invest in structures that will help them best to move in their environment. For example: Fish invest in fins to swim in aquatic environment, land animals invest in legs, leg-like structures and wings).
- Animals which do not move have some form of mechanism to bring food to their body.

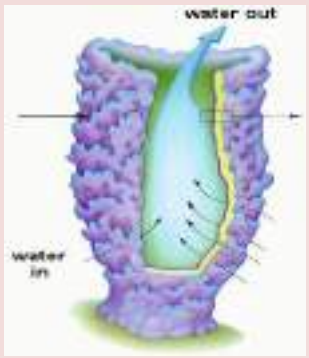
Example

Sponges are sessile and therefore the food enters the body with the water current. As water moves in and out of the body, **microvilli**, lining the inner part of the body traps food.



Source: *www.hdwallpapers.in*

Source: *www.circusystem.weebly.com*



Source: *www.uic.edu*

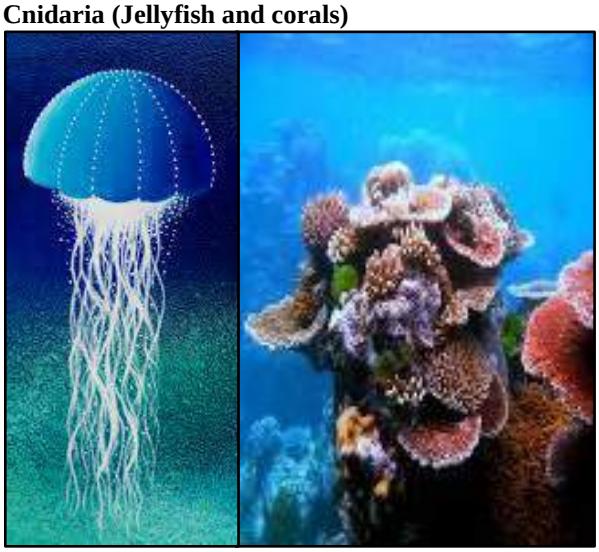
Movement, Support and Protection in Invertebrates

- Invertebrates are animals which lack a backbone.
- The invertebrate animals belong to phylum:

Porifera (Sponges)

Source: *www.youtube.com*

Cnidaria (Jellyfish and corals)



Source: *www.reddit.com*

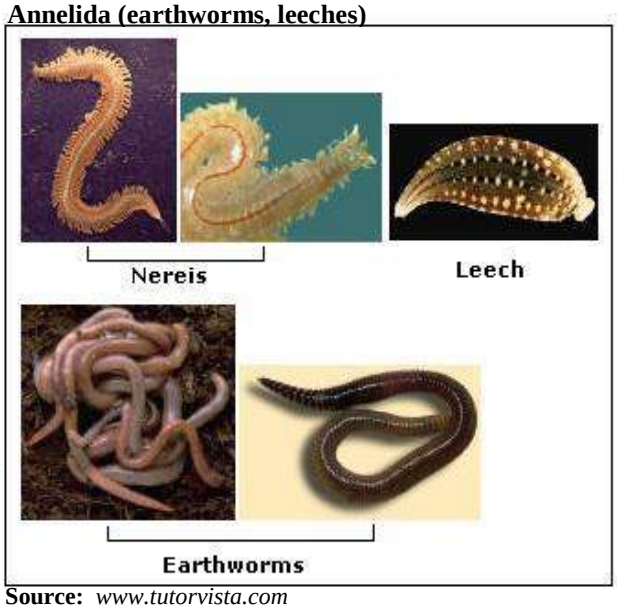
Platyhelminthes (flukes, tapeworms, flatworms)

Source: *www.blog.nus.edu.sg*

Aschelminthes class Nematoda (roundworms)

Source: *www.froggynaan. com*

Annelida (earthworms, leeches)



Source: *www.tutorvista.com*

Mollusca (snails, bivalves)

Source: *www.biovik.blogspot.com*

Echinodermata (Sea stars)

Source: *www.evolutionevidence.org*

Arthropoda (Insects)

Source: *www.portaldoprofessor.mec*

- This year we will only look at the support, movement and protection in animals belonging to phylum Cnidaria, Annelida and Arthropoda.

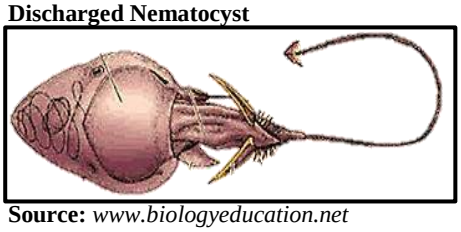
1. Hydrostatic Skeleton: Cnidarians and Annelids

- Cnidarians (jelly fish) and annelids (earthworms) do not have a skeleton.
- Instead, they support their bodies with a hydrostatic skeleton.
- A hydrostatic skeleton is a fluid filled body cavity.
- Since cnidarians and annelids are not very large-sized and highly active animals, hydrostatic skeleton is sufficient for them.

Protection

- Despite the ability to allow gas exchange with the surrounding water, a hydrostatic skeleton does not provide any form of protection from dehydration and predation.

Discharged Nematocyst



Source: *www.biologyeducation.net*

- All cnidarians are aquatic and therefore do not face a dehydration problem. For protection from predators and for killing prey (obtain food), many cnidarians have poisonous stingers called nematocyst.

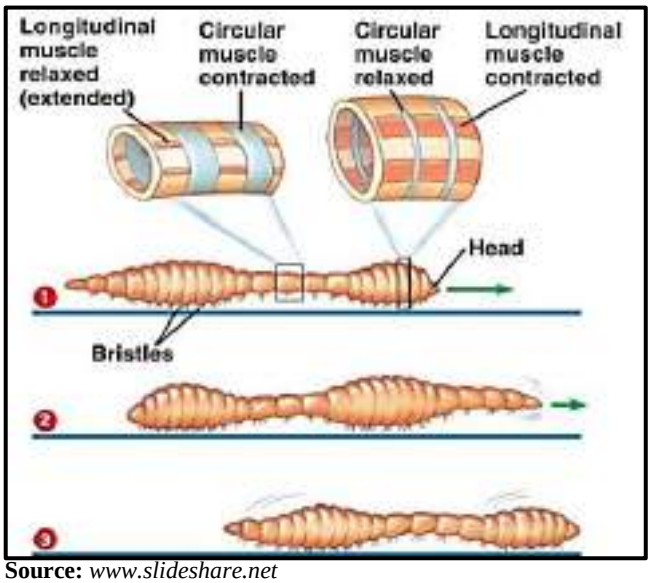
- Terrestrial annelids protect themselves from both dehydration and predators by staying underground. Earthworms have rigid hairs (bristles) on their bodies which can grip tightly onto the soil, making it difficult to be pull out of the ground.

Support and Movement

- The hydrostatic skeleton gives shape to the cnidarian's body. For movement, they rely on the contraction of the muscle to and the internal fluid to move. Cnidarians do not need much support structures because they are buoyed (upward thrust) by water.

- The hydrostatic skeleton also gives shape to the annelid's body. For movement, terrestrial annelids, especially earthworms, rely on the contraction of the muscles and the internal fluid to create peristaltic movements. To move, it pushes its internal fluid forward by contracting circular muscles in one body region and relaxing the muscles in another. The worm contracts the muscles in a wave down its body, moving itself forward. The bristles on the bottom side help it grip the soil as it pushes its body forward, region by region.

Use of Hydrostatic Skeleton and the Muscles to Move



Source: *www.slideshare.net*

2. Exoskeleton: Arthropods

- Exoskeleton is the skeleton outside the body.
- It is the hard outer covering.
- Arthropods (insects, crabs, prawns, spiders) have exoskeleton.
- Arthropods exoskeleton is made of chitin and protein.
- Chitin is a strong and stiff carbohydrate.

Source: *www.davidlnelson.md*

Advantages of Exoskeleton	Disadvantages of Exoskeleton
➢ Exoskeletons provides **protection** against: ▪ predation ▪ damage of the internal tissues ▪ dehydration in terrestrial animals	➢ Exoskeletons **cannot grow** and therefore the animal needs to shed the exoskeleton (moult; ecdysis) in order to grow. ➢ During the moulting period the animal is prone to diseases, predation and terrestrial animals to dehydration. ➢ Animal has to invest a lot of energy into making new exoskeletons. ➢ Exoskeletons are **very heavy** and therefore the animal has to spend a lot of energy to carry it around. Also, due to the weight there is size limitation especially the terrestrial ones who do not get similar support as the aquatic ones (buoyancy)

Protection

- Apart from the exoskeleton, the arthropods also possess other structures which aid in their protection.
- Some such structures are:
  - Wings to fly away in most of the insects.
  - Jointed appendages to escape predators and catch prey efficiently.
  - Fierce mouth parts with poisonous stings (bees, centipedes), venom (spiders) or chelicerae (crabs claws)

Support and Movement

- Support to the body provided by exoskeleton.
- Movement is via jointed appendages (limbs). Some have wings to fly and some aquatic ones have the appendages modified to can aid in swimming.

3. Endoskeleton in Vertebrates

- Vertebrates have internal skeletons (endoskeleton).
- Hard skeletons of bone and cartilage are inside the body.
- The endoskeleton provides support, places for muscle attachment and protects the internal organs.
- All vertebrates share similar bone structure - a skull, a rib cage and a vertebral column.
- The vertebrate animals are:
  - Fish
  - Amphibians (frogs)
  - Reptiles (snakes, lizards, iguanas and crocodiles)
  - Aves (Birds)
  - Mammals

Advantages of Endoskeleton	Disadvantages of Endoskeleton
➢ Light yet strong and flexible to allow quick escape from predators or to catch prey. ➢ Lighter than the exoskeleton ➢ Can grow as the organism grows (no need to moult)	➢ Endoskeleton cannot be moulted therefore any fatal damage to it is almost permanent.

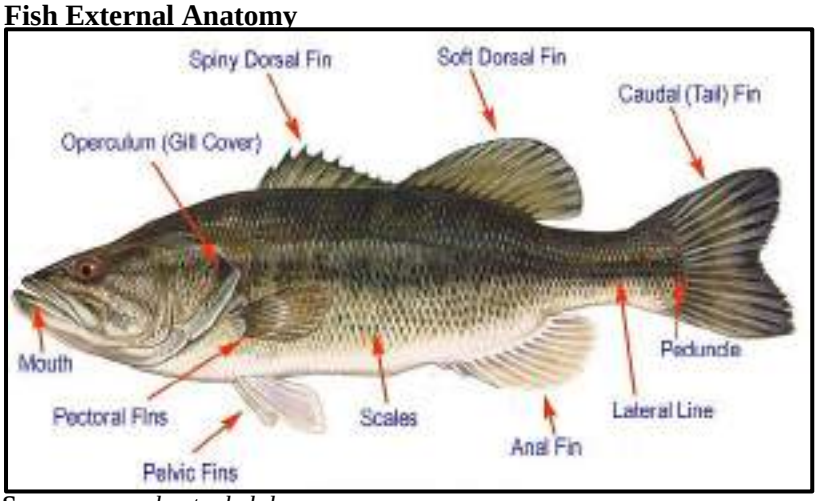
1. Fish

- All fish are aquatic therefore they do not need adaptive structures which prevent dehydration.

Protection

- Scales- first line of defence just like our skin.
- Some have poisons, sharp teeth, camouflaging ability, electric, stings and spines.
- Operculum (bony gill cover) to protect the tender gills.

Fish External Anatomy



Source: *www.kentuckylake.com*

Support

- Buoyancy (upthrust of water) reduces the pull of the gravity experienced by fish.
- Fish do not need a skeleton as strong as those of terrestrial vertebrates. Sharks have skeleton composed of cartilage which is light-weight.

Movement

- Fish skeletons are very well adapted for swimming.
- Most fish propel themselves forward by swishing their caudal fin back and forth. Their dorsal, caudal and fins help keep the fish from rolling. The pectoral, pelvic, and caudal fins steer.
- Most fish are shape for speed. Their narrow, pointed bodies reduce friction with water.

2. Amphibians and Reptiles

- Amphibians (frogs) live a part of their life in water and part of it on land. While on land, they need adaptive structures that provide support against the strong pull of the gravity.
- Likewise there are reptiles capable of both living in water and on land e.g. Crocodiles, turtles and some snakes.

Protection

- Adult amphibians have no protective covering over their skin because they breathe partly through their skin.
- This makes them vulnerable to both dehydration and predators.
- In order to prevent dehydration, amphibians avoid sunlight and live in moist habitats. For example frogs, they mostly come out at night and during the day when it's raining.
- For protection against predators, amphibians have the ability to camouflage-blend in with the environment. Some amphibians also change the colour of their skin to match the colour of their current environment.
- Furthermore, some have poison glands. Frogs secrete white toxins near the head region to
- signal the predators to stay away

Camouflaged Frog

Source: *www.dreamstime.com*

Frog Changing Skin Colour

Source: *www.livescience.com*

Fiji Tree Frog

Source: *www.fijiguide.com*

- Reptiles have scaly skin which is thick enough to protect them from dehydration and predators.
- Reptiles have very good camouflaging ability and some can also change skin colour.
- Other defence mechanisms include:
  - spitting venoms (cobra snakes)

- poisonous bites (some snakes and lizards)
- hissing sounds (snakes)
- sharp teeth (crocodiles and alligators)
- autotomy - lose the tail which will later grow back (lizards)

Support and Movement

- ❖ Tadpoles can swim but when they develop into adult frogs and come to live on land, they use their hind legs to jump or hop.
- ❖ Other amphibians like toads (bigger version of frogs), salamanders and newts can walk; legless caecilians slither like a snake.
- ❖ Land reptiles crawl on their limbs- crocodiles, iguanas and lizards.
- ❖ Aquatic reptiles can swim; turtles have flippers to swim.
- ❖ Legless land reptiles such as snakes slither on the ground.
- ❖ Amphibians and reptiles with limbs support their weight on it. These limbs project to their sides.
- ❖ Such a body design is not very efficient because the weight of the body disables them from standing up or moving quickly. Try standing with your legs bent and out to the sides, like a reptile. Feel how much more muscle exertion this weight distribution requires?

Common Reptiles Found in Fiji

Black and white snake (Local Name: dadakulaci)

Source: *en.wikipedia.org*

Pacific Boa (Local Name: Bolo)

Source: *www.snipview.com*

Crested Iguana (Local Name: Vokai, Vokaivotovoto, Saumure)

Source: *www.flickr.com*

Green Turtle (Local Names: Vonudina, Ika du)

Source: *en.wikipedia.org*

Hawksbill Turtle (Local Names: Taku)

Source: *www.marinebio.net*

Leatherback Turtle (Local Names: Taba-i-walu, Tutuwalu, Vonudakulaca)

Source: *www.manataka.org*

Fijian Copper-headed Skink (skink = small lizard)

Source: *www.ryanphotographic.com*

Onoilau skink

Source: *www.iucnredlist.org*

Rotuman Forest Gecko

Source: *www.ryanphotographic.com*

3. Aves (Birds)

Protection

- The main protection in birds is the ability to fly away from danger.
- It is an effective means of escape but consumes a lot of energy.
- Many birds also have 'call-out warnings'- special sounds to warn their peers of the danger around. Feathers help protect their skin from dehydration and to keep the body warm.

Support and Movement

- Birds have wings to fly and hind legs on which it can stand, walk and hop.
- Adaptations for flight are:
  - Light-weight skeleton
  - Some bones are hollow
  - No teeth
  - Keel- extension on the breastbone to which wings attach.
  - Feathers extend the wing surface area for pushing against the air in flight without adding much weight. These feather extensions are also crucial for adjusting speed and direction while in the air.
  - Stream-lined body structure
  - Some birds keep their reproductive organ tiny and only enlarge it during breeding season.

Did You Know?

There are birds that don't fly such as Penguins, Kiwi birds and Ostriches. These birds protect themselves with sharp claws on the legs or sharp beaks or by running fast (ostriches can run at a speed of 45 miles/hr)

4. Mammals

Protection

- Have fur/ hair to retain body heat, reduce water evaporation from the skin and protect the skin.
- Most mammals' fur is coloured to camouflage with the habitat.
- Others defend themselves with teeth, horns and\or claws.

- Mimicry is another defence method in which the least dangerous species copies the features of the species that is dangerous to the predator.
- A few species of mammals have spines or hardened skin.
- Skunks can spray a burning chemical that stinks horribly.

Source: *www.faithfirm.com*

Support and Movement

- Mammals are among the fastest animals.
- Strong endoskeletons support their weight.
- Legs are not protruding sideways as in the case of amphibians and reptiles and therefore can run or walk very fast.
- Well-developed muscles power the movement.
- Aquatic mammals (whales and dolphins) move by swimming.
- There are also some mammals which fly such as bats and flying squirrels.

SUMMARY TABLE FOR MOVEMENT, SUPPORT AND PROTECTION IN ANIMALS							
	Invertebrates			**Vertebrates**			
	Cnidarian	**Arthropod**	**Annelid**	**Fish**	**Amphibian and Reptiles**	**Aves**	**Mammals**
Example	Jelly Fish and Hydra corals	Insects, crustaceans	Earthworms	Sharks and Bony Fish	Frog and Snakes	Birds	Bears, dogs, humans, cats
Movement	▪ Swim (muscle contractions)	▪ Jointed appendages to walk, hop or swim ▪ Wings (insects)	▪ Peristaltic motion created by the contraction of circular and longitudinal muscles with aid from hydrostatic skeleton.	▪ Swim	▪ Jumping on hind leg (frogs) ▪ Slithering ▪ Crawling	▪ Flying ▪ Hoping ▪ Walking	▪ Flying ▪ Hoping ▪ Walking ▪ Swimming ▪ Running
Support	▪ Buoyancy ▪ Hydrostatic skeleton	▪ Exoskeleton made of chitin	▪ Hydrostatic skeleton ▪ Bristles to grip the soil when moving	▪ Buoyancy and Endoskeleton ▪ Streamlined body to swim	▪ Endoskeleton	▪ Endoskeleton ▪ No teeth ▪ Keel ▪ Hollow bones	▪ Endoskeleton ▪ Walking limbs not protruding sideways
Protection	▪ Nematocyst(stinging cells)	▪ Exoskeleton to prevent dehydration ▪ Fierce mouth parts with poisonous stings, venoms, or claws ▪ Fly away	▪ Live under the soil in moist areas to prevent dehydration	▪ Scales ▪ Sharp teeth ▪ Electric ▪ Stings ▪ Operculum protects the gills	▪ Live in moist areas (frogs) ▪ Scaly skin to prevent dehydration (reptiles) ▪ poisonous bites ▪ hissing sounds ▪ sharp teeth ▪ autotomy (lizards) ▪ camouflage	▪ fly away ▪ claws ▪ run fast ▪ call-out signals	▪ run ▪ walk fast ▪ poisons ▪ sharp claws, teeth or horns ▪ fly away ▪ stinky spray ▪ camouflage ▪ mimicry

SELF TEST

1. How are the support needs of aquatic organism different from those of terrestrial organisms? What are the reasons for these differences?

2. Why do plants have limited movement abilities in comparison to active animals?

3. Plants produce more food than they consume. What may have selected for this over-production?

4. Compare and contrast the support systems of herbaceous and woody plants. Explain the adaptive value of their differences.

5. What disadvantages might climbing plants face because they depend upon other structures for support?

6. How do epiphytes support themselves?

7. Explain turgidity and flaccidity of a cell with reference to osmotic movement of water.

8. Compare and contrast between hydrostatic skeleton, exoskeleton and an endoskeleton. For each type of skeleton, identify an organism which possesses it and the adaptive value of that skeleton to that particular organism.

9. Compare adaptations for protection, support and movement in an earthworm, a cockroach and a rat.

10. Identify problems that humans would face if it had a: (1) hydrostatic skeleton and (2) exoskeleton?

11. Compare methods of protection, support and movement in a fish and a mammal.

12. While most turtle species in the world are terrestrial, sea turtles are more common in Fiji. Sea turtles return to land only to lay eggs. How are sea turtles adapted for movement in their aquatic environment?

13. Describe adaptations of birds which aid in successful flight.

BI 12.1.4.6 SENSITIVITY AND COORDINATION

Organisms (plants and animals) need sensory and coordination abilities to find resources, avoid danger, and to time their reproduction with favorable seasons. The accuracy and speed of an organism's sensory and coordination abilities match the organism's mobility. Sessile organisms, such as hawks, have complex sensory systems and rapid, accurate motor capability.

Organism senses the stimuli that are important to their way of life. For example, plants and photosynthetic protists can sense sunlight direction. Grasshoppers have ears in its abdomen to quicken its reflex to jump and hawks have a vision like a telescope which can locate small preys on the ground far below.

Endocrine vs. Nervous System

- In most organisms, both the endocrine (glands and hormones) and the nervous system help coordinate body response to stimuli.
- Stimulus/ stimuli are things that cause a response in organism. For example, the smell of food can be a stimulus to more saliva production in your mouth.
- The endocrine system uses chemical messenger called hormones to coordinate slow and extended responses such as growth and metabolic rate.
- On the other hand, the nervous system communicates by rapid electrical impulses for immediate sensory and coordination needs as a vision and movement.

Endocrine System	Nervous system
➢ Consists of glands and hormones ➢ Slow ➢ Long term response ➢ Chemical messenger	➢ Consists of neurons, nerve cells and fibres ➢ Immediate and quick ➢ Short-term response

PLANTS: SENSITIVITY AND COORDINATION

Plant Hormones

- Plants coordinate responses to stimuli using chemical messengers called **hormones**.
- Plants produce variety of hormones that diffuse through the plant to coordinate tropisms.
- Apart from controlling tropisms, hormones also coordinate growth and reproduction in plants.
- Flowering, fruiting-ripening and falling of leaves in seasonal plants (eg. frangipani) is also controlled by hormones.
- Plant hormones coordinate their growth and reproductive responses to their environment. If hormones were not there to do this, the roots would be growing randomly with some of it growing up towards the sky; some branches would be flowering and fruiting while others would be dropping leaves.
- Also, if angiosperms of the same species flowered at different times of the year, their chances of pollination would fall steeply.

- In Plants hormone may:
  - Induce different responses in different tissues.
  - Induce different responses at different times of development in the same tissue
  - Directly affect the activity or production of other hormones.
  - Induce different responses depending on concentration in a given tissue.

- The sensitivity of a plant tissue to a given hormone may be altered either by:
  - Changing hormone concentration in the target tissue.
  - Altering receptor sensitivity to that hormone in the target tissue.

Hormones	Role
Auxin	➢ Responsible for cell division and growth in cell size. ➢ Involved in differentiation of vascular tissue ➢ Control cellular elongation ➢ Prevention of abscission ➢ Involved in apical dominance and various tropisms ➢ Stimulate the release of ethylene to enhance fruit development. ➢ Example: IAA (indole acetic acid), IBA (indole-3-butyric acid)
Cytokinins	➢ Promotes cell division in plant roots and shoots, and promote the growth of buds. ➢ Cytokinins increase cell division by stimulating the production of proteins needed for mitosis. ➢ Every time the process of mitosis occurs, a new cell is formed to move to the end of the plant, and this makes it longer or taller. ➢ Affect cell division, delay senescence and activate dormant buds. ➢ Example: Zeatin
Ethylene	➢ Responsible for senescence (aging) processes. ➢ Promotes the ripening of the fruit. ➢ Ethylene also affects many other plant functions such as: - abscission of leaves, fruits, and flower petals; - drooping of leaves; - sprouting of potato buds; - seed germination; - stem elongation in rice - flower formation in some species.
Abscisic acid (ABA)	➢ Maintains dormancy in seeds and buds ➢ stimulates the closing of stomata
Gibberellins (GAs)	➢ Responsible for cell division and growth in cell size. ➢ Initiate mobilization of storage materials in seeds during germination ➢ Causes elongation of stems ➢ Stimulate pollen tube growth

Did You Know?

Plants can communicate.

Plant neurobiology is an emerging field of plant sciences where the researchers are trying to understand the complexity involved in plant communication.

Previously, 'talking tree' research was regarded stupid but in 1983 two researches revealed that willow trees, poplars and sugar maples can warn each other of the insect infestation. The infested trees release chemicals which the neighbouring plants can sense and start preparing its defence mechanisms.

There is an interesting English movie based on plant communication.

Movie: The Happening

Do watch if you get your hands on a copy.

ANIMALS: SENSITIVITY AND COORDINATION

1. Animal sense stimuli and coordinate responses with three types of structures: (1) Receptors; (2) communication system and (3) effectors.

(1) Receptors

- Responsible for sensing stimuli.
- Organisms have receptors for environmental information useful to their survival.

❖ For example, humans have a high concentration of touch receptors on the fingertips.

❖ Photosynthetic protists-*euglena* have "eyespot" to sense light.

❖ Python snakes can perceive temperature by sight to find prey and all the snakes are highly sensitive to vibrations. Snakes can sense very faint vibrations in both the air and the ground using their inner ear.

❖ Sharks have sensory receptors (ampullae of Lorenzini) which detect electric fields created in the waters by other swimming creatures.

(2) Communication system

- Carries message between receptors and effectors.
- Simple and sessile organisms have very basic communication system.

❖ For example, hydra has only a nerve net with no processing centre. A vertebrate, by comparison has an extensive neural network with a brain and a spinal cord centre. Most animal use both neural impulses and hormones for communication within the body.

(3) Effectors

- Are muscles and glands that act out responses.
- Fast animals require complex nervous systems to keep up with their sensory and coordination needs.
- Selection pressure for increased speed has led to several major neural developments along the evolutionary trend.
- These include accurate sensory structures, complex motor ability and the evolution of brains.

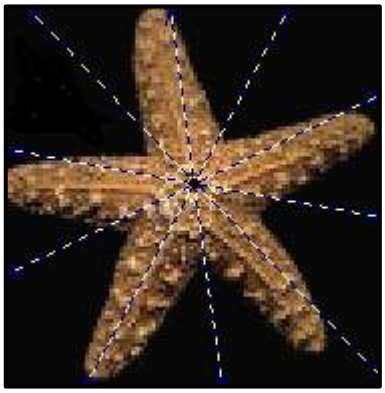
Body Symmetry

1. Asymmetrical Animals

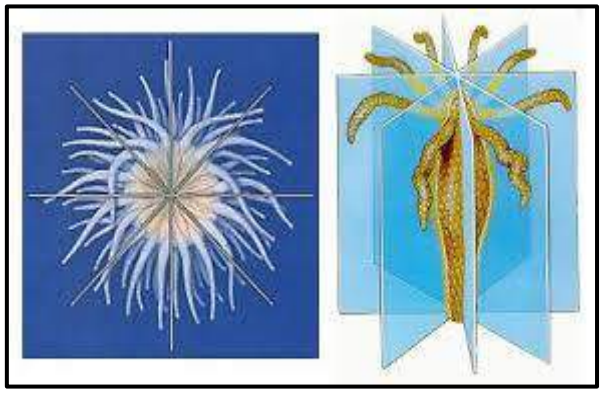
- No body symmetry.
- For example, Sponges.

2. Radially Symmetrical Animals

- Animal can be divided into similar halves by passing a plane through the central axis.
- These animals have the ability to sense from all directions.
- Such animals are mostly sessile (do not move) or sedentary (move very slowly) and therefore do not need very complex nervous system.
- They mostly possess a simple nerve network with no centralized sensing or processing.
- Example: Cnidarians (jelly fish and hydra) and Echinoderms (star fish, sea urchin etc) as adults.



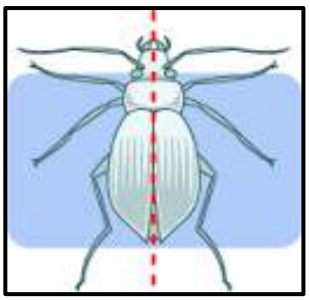
Source: *jwilson.coe.uga.edu*



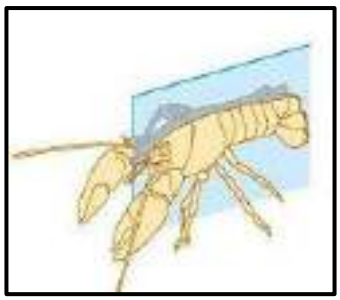
Source: *www. pixgood.com*

3. Bilaterally Symmetrical Animals

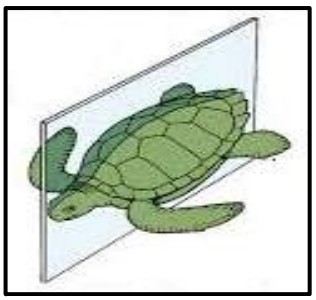
- Animal can be divided into two (bi= two) matching halves by passing a plane through the central axis.
- Have left and right sides.
- The head end is the first to come in contact with food or danger so natural selection favored sensory ability centralized in the head.
- In turn, this favored the development of nerve centers to process the sensory input.
- Nerve centralization allowed evolution of increasingly complex animal nervous systems.
- Example: flatworms, annelids, arthropods, molluscs, vertebrates.



Source: *gallery4share.com*



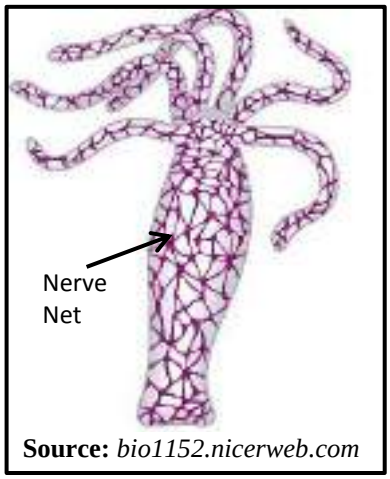
Source: *www.studyblue.com*



Source: *www.mhhe.com*

Sensitivity and Coordination in Invertebrates

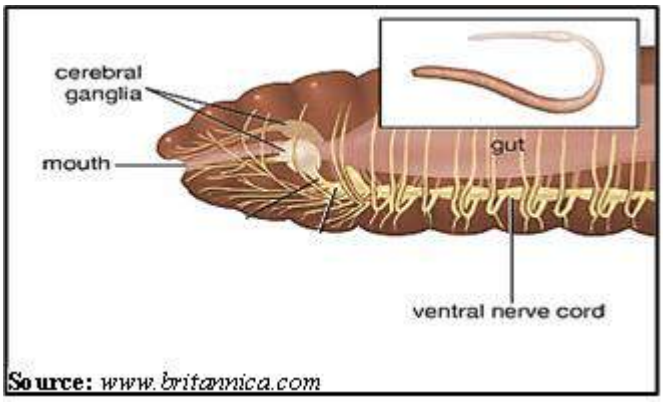
1. Cnidarians



Source: *bio1152.nicerweb.com*

- Simplest nervous system known as **nerve net**.
- Cnidarians have simple life which involves stinging of prey and stuffing them into their mouths.
- They have touch receptors in their skin.
- When anything stimulates these receptors, a reflex action begins.
- Reflex action refers to quick responses which do not involve brain.
- The stimulated sensory receptors signal poison cells to sting the potential prey and tell the tentacle muscles to pull the prey into the mouth.

2. Annelids

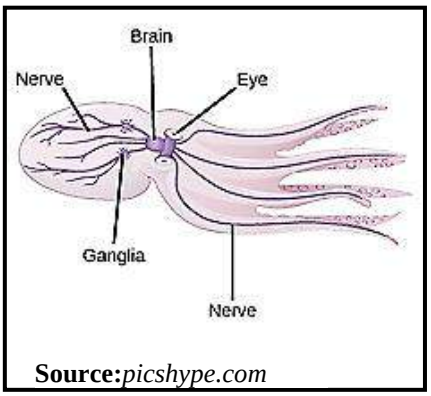


Source: *www.britannica.com*

- Simple bilateral organisms which have a back and a front region.
- Complex sensory and coordination abilities in comparison to cnidarians.
- Neurons concentrated into clusters called **ganglia**.
- Ganglia are connected to each other in chain-like fashion by two nerve cords.
- Nerve cord is a bundle of neurons that run the length of the organism.
- Ganglia in the anterior end (cerebral ganglia) functions like a 'mini' brain.
- This brain processes stimuli and, with the nerve cord, coordinates movements.
- Sensory abilities limited to light intensity, touch and chemical sensitivity.
- Earthworms avoid light to prevent dehydration- they need their skin to be moist in order to breath. The touch and chemical sensitivity allows it to search for food and avoid dangers.

3. Molluscs

- Different classes within this phylum greatly differ in terms of the development of their nervous systems.
- Bivalves (*kai*) and snails are slow-moving – they have a simple nerve network controlled by a brain-like neuron concentration.
- Squid and octopus are very fast swimmers- they have well developed eyesight and a large and complex brain that allows them to respond very quickly to food and to danger.

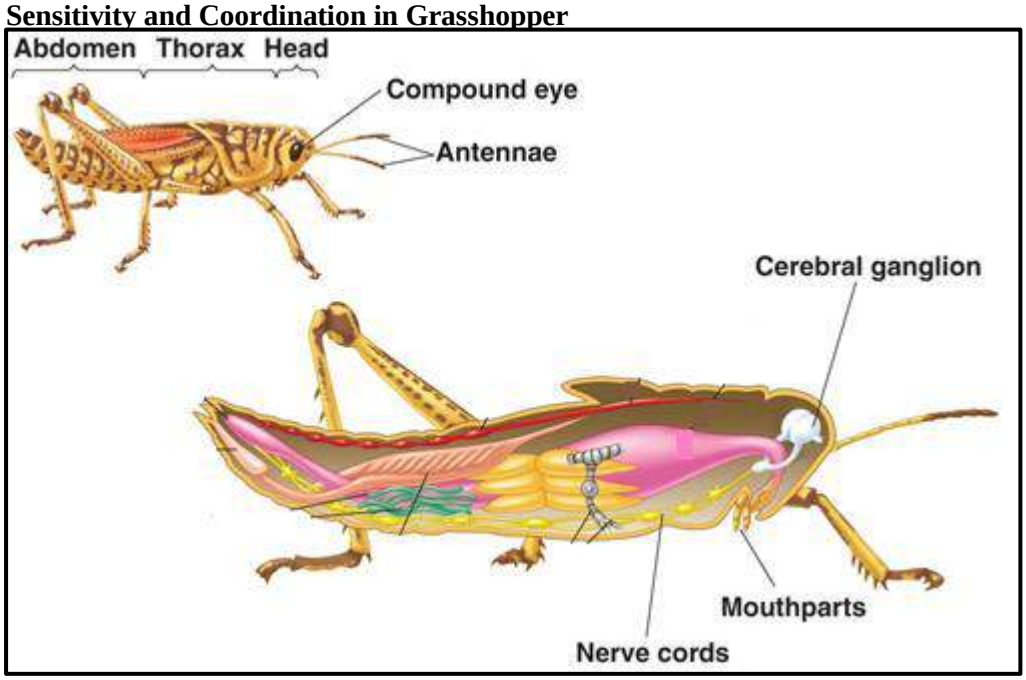


Source:*picshype.com*

4. Arthropods

- Of all invertebrates, arthropods have the most developed nervous systems.
- All have a dorsal brain and a ventral nerve cord with ganglia from which lateral nerves extend in each segment.
- These miniature brains + nerve cord often exert as much control over coordination as the real brain in the head.
- In arthropods, class Insecta (insects) have the most developed sensory and coordination abilities especially those that can fly.
- Insects and some other arthropods have compound eyes which help them detect quick movements.
- The location of other receptors varies with the insect's lifestyle.
- Most insects have antennae, which often house receptors for sound, smell, taste and touch. Flies have taste receptors on their feet, so they know upon landing if they have found a tasty meal. Grasshoppers have ears in their abdomen section. At the first sound of danger, such as the rustle of an approaching chicken, a jumping reflex begins.

Sensitivity and Coordination in Grasshopper



Source: *www.studyblue.com*

Sensitivity and Coordination in Vertebrates

- Vertebrates have the most elaborate nervous system in the animal kingdom.
- The complex abilities of their nervous systems rest on the three major developments:
  (1) Well-developed **sense organs**,
  (2) complex **motor structures** and
  (3) Centralized **processing and control center**.

(1) Sensing

- Well-developed sense organs allow vertebrates to take in large amounts of detailed information about their environments.
- Fast moving animals need powerful sensory organs not only to avoid running into things, but also to find enough food to support their high energy demands.
- Sense organs that are the most developed, depends on the animal's lifestyle.
- For example, Birds have sharp eyesight to avoid flying into things. Mongooses have an excellent sense of smell in order to track their prey. Bats discern the precise location of tiny insects by bouncing sounds against them.

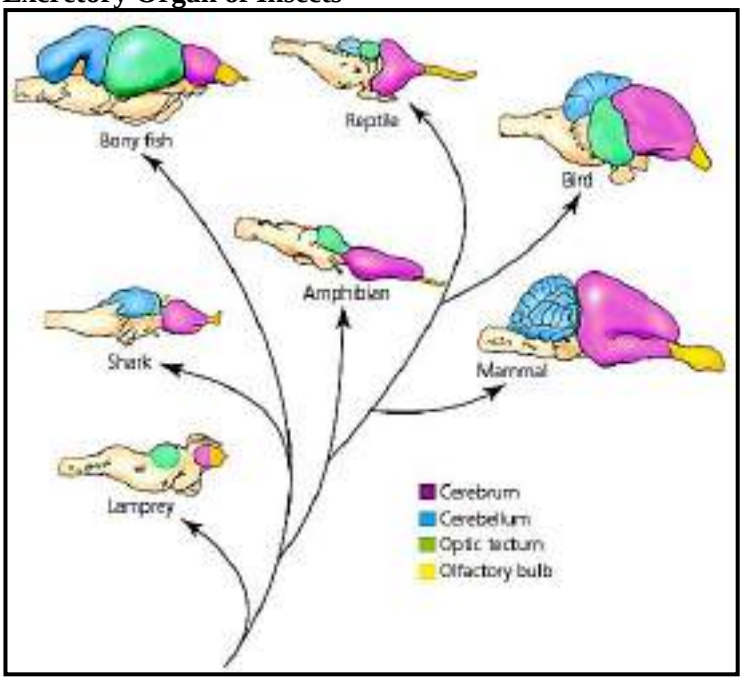
(2) Effect Output

- The vertebrate's nervous system coordinates dozens of different muscles to make smooth, rapid movements.
- Simultaneously, the brain directs the heart, diaphragm, stomach walls and other involuntary muscles.
- The extensive, finely tuned muscular system of a vertebrate works precisely as directed by the brain and spinal cord.
- At the same time, hormones from the endocrine system manage metabolic rate, emotions, growth and other gradual processes requiring coordination.
- The brain tells the gland how much of which hormones to produce and in return hormones influence the brain's directions to some extent.

(3) Processing

- Vertebrates have **central nervous system** (CNS) consisting of a brain and spinal cord.
- It provides vertebrates with more intelligence and more complex sensory and motor abilities than any other animal group.
- **Thinking** is done by the cerebrum. The rest of the vertebrate brain is devoted to reflex action such as heart beat, breathing and muscles coordination.
- The most ancient vertebrates, the fish and amphibians, have tiny cerebrums. Reflexes coordinate nearly all of their actions.
- The most recently evolved class, the mammals, proportionately has the largest cerebrum.
- A large cerebrum means greater intelligence. Some birds, reptiles and mammals are capable of complex processes such as memory, learning and even emotion.
- The 'highest' mammals, such as chimpanzees, humans and dolphins, can think and reason. The cerebrum cover, called the cerebral cortex, has evolved into a complex information processing centre in mammals.
- The highly developed human cerebral cortex has allowed us to develop the tools and language upon which we have built our entire civilization.

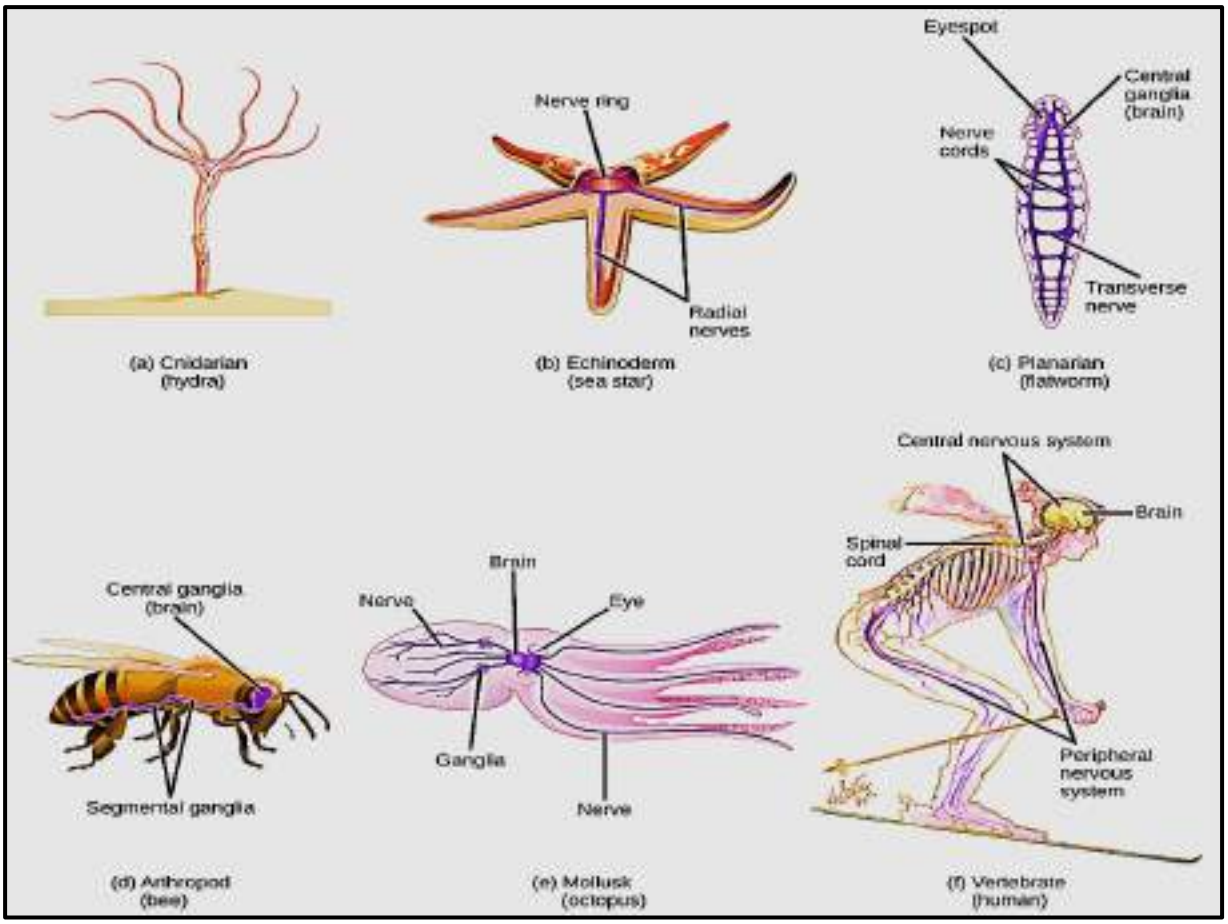
Excretory Organ of Insects



The diagram shows the evolutionary trend observed for the size of the vertebrate brain. The higher animals with more efficient body had a bigger cerebrum. For example: the mammals.

Source: *www. thehumanbrain1.blogspot.com*

Evolutionary Trend



Source: *www. cnx.org*

SELF TEST

1. Identify the difference between a reflex action and an 'intelligent' action.

2. Describe the trend in evolution of nervous system using the following animals:
(i) cats; (ii) ants; (iii) earthworms; (iv) jellyfish; (v) lizards; (vi) frog and (vii) birds

3. Explain the difficulties that jellyfish would face with bilateral symmetry. How has it overcome that difficulty?

4. Identify some sensory organs of flies (insects).

5. What are some of the differences between the nervous system and the endocrine system?

6. Identify whether the following action is complete by the nervous system or the endocrine system:

a. Quickly moving away the fingers after touching a hot pot.
b. Growing in height from birth till the end of puberty.
c. Release of adrenalin in a dangerous yet exciting situation.
d. Scratching your itching head.
e. Blinking eyes.
f. Feeling sad after being scolded by your teacher.

7. Explain why the sensitivity and coordination ability of parrots will differ from that of an earthworm.

8. Identify the sensory organ/structure that has enabled the following organisms to be well adapted to their environment:

a. *Euglena* species (protist)
b. Sharks
c. Snakes
d. Grasshoppers
e. Birds

9. Snails and octopus both belong to the phylum Mollusca. Reflecting on the lifestyle of each, explain the difference in their sensitivity and coordination.

BI 12.1.4.7 REPRODUCTION

Survivability and Continuity

Any organism well equipped with the best adapted nutrition, transport, excretion and other body systems is still not regarded successful if it cannot reproduce and pass on its genes.

Organisms have been designed for **survival** and **reproduction**.

All of the body systems (nervous, digestive, endocrine etc.) help the organisms survive. However, for their species to survive, the organisms must reproduce.

Nature selects against organisms poorly designed for survival and reproduction. These organisms have fewer off springs and their genes eventually disappear from the population in successive generations.

On other hand, nature selects for the survival of fittest. These organisms survive well in their environment and also reproduce successfully thus passing their genes over generations.

Evolutionary Trends in Reproductive Strategies

Plant and animals species have developed many strategies for reproduction, all of which attempts to insure survival of the species.

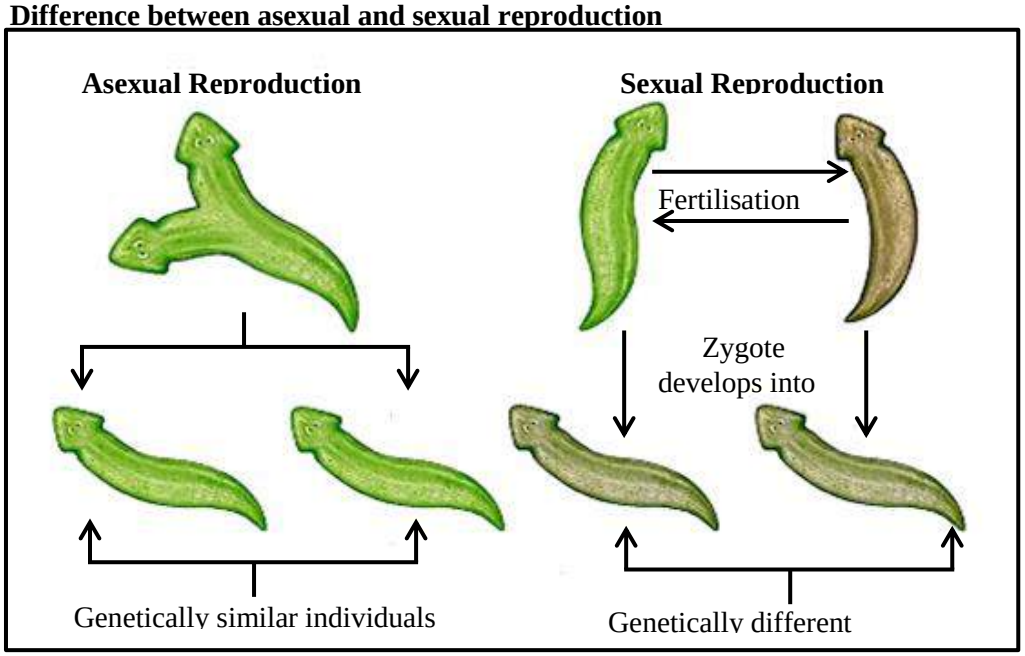
The earlier evolved plants produced many spores or seeds to ensure its dispersal and survival. However, as the higher plants evolved, lesser seeds were produced, several dispersal mechanisms were involved and were enclosed in fruits (angiosperms).

Likewise, the earliest animals produced many eggs thus many offspring but did not provide parental care. Later as the higher animals evolved, lesser offspring were produced but more parental care was provided.

1. **Asexual and Sexual Reproduction**

- Some organisms are capable of reproducing asexually.
- Asexual reproduction involves cell division of a single parent by mitosis to produce genetically offspring.
- Asexual reproduction produces little genetic variation and therefore asexually produced populations are unlikely to survive severe environmental changes.
- Asexual reproduction is favoured in stable environments.
- Changing conditions favour sexual reproduction, where two haploid gametes produced by meiosis come together to produce a unique individual.
- Sexual reproduction produces genetically varying offspring, at least some of which are likely to have adaptations to survive environmental changes.
- Evolution shows a slow trend towards sexual reproduction.

Difference between asexual and sexual reproduction



Source:*www.slideshare.com*

2. Haploid and Diploid Stages

- When sexual reproduction first evolved, the diploid life stages of organisms were very small. It lasted just long enough to produce new haploid offspring.
- Mosses and sexually reproducing algae spend most of their lives as haploid organisms.
- However, as evolution proceeded, diploid life stage in organisms became more prominent. Organisms had longer diploid life stages. Ferns, seed plants and animals spent almost their entire lives in a diploid stage.
- For example, we humans, one of the highest evolved animals spend our entire life as diploid organism and the only stage that is haploid in our life is our gametes (eggs and sperms) which also unite during fertilization to restore diploidy.

3. Reproduction on Land vs. Water

- Life began in the sea.
- Eventually, when the oceans became crowded with competing organisms, natural selection began to favour organisms that could adapt to a land environment.
- However, terrestrial life required new adaptations for reproductions.
- On dry land, sperm cannot swim to eggs and embryos need protections from dehydrations.
- Adaptations for reproductions on dry land evolved as terrestrial organisms evolved.
- For example, bryophytes (moss) the first land plants still required water for fertilization to occur and therefore, they were very small in size, were low lying and were restricted to moist habitats. As plants evolved, the gymnosperms started producing seeds (cones) which was the reproductive structure and did not require water for fertilization to occur. In the highest evolved plant, that is, the angiosperm, the reproductive structures were enclosed within the flower. There was no need for water for fertilization to occur and the developing embryo was well nourished by the endosperm.

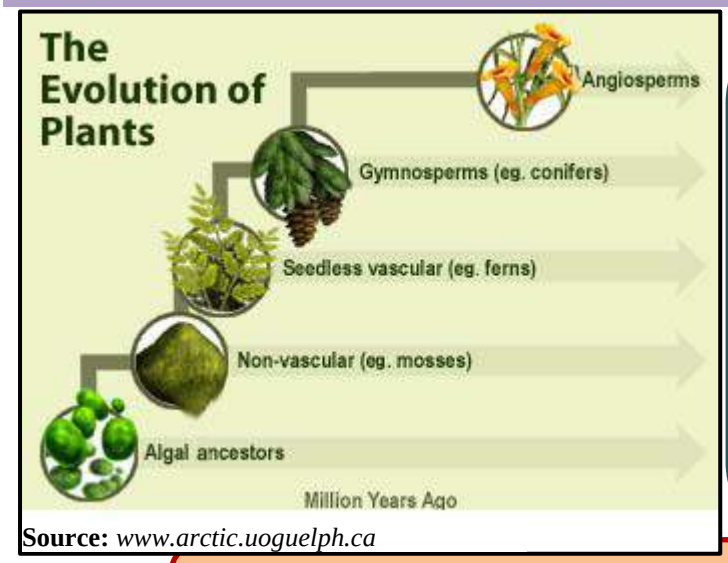
4. Parental Investment in Offspring

- The more offspring an organism has the less energy it can invest in each.
- For example, angiosperms could produce many seeds with tiny endosperms or fewer seeds with larger endosperms or fewer seeds with large endosperms. Seedlings with tiny endosperms have a low survival rate because they must quickly start producing food for themselves; Seedlings fed by large endosperms have more time to establish roots and leaves before they must support themselves.
- Generally, the more offspring an organism has, the lower the chances are for the offspring's survival.
- Natural selections favour organisms that produce the highest number of surviving offspring.
- Thus, parents must find a balance between having more offspring with less investment for each offspring or have fewer offspring with a greater investment in each.
- Evolution shows a trend towards lesser offspring and more parental care.
- The most recently evolved groups of organisms, the mammals and birds, invest more energy in each offspring. They have very few offspring compared to other animals, but their offspring have a high survival rate.

Source: *www.countryfile.com*

Source: *www.imgbuddy.com*

PLANTS: EVOLUNTIONARY TRENDS IN REPRODUCTION



Source: *www.arctic.uoguelph.ca*

In plant evolution, **three** trends observed are:

1. Sexual reproduction rather than asexual.
2. Diploid stages of life dominant rather than haploid.
3. Adaptations for terrestrial reproduction such as non-swimming sperm and protected embryos.

Sporophyte = diploid (2n); Example: leaves, roots, stems

Gametophyte = haploid (n); Example: ovules, eggs, sperms and pollen

N = # of chromosomes

1. ALGAE

- Various reproductive methods.
- Most reproduce asexually by divide in half via mitosis to produce new algae plants.
- Some capable of both asexual and sexual.
- Such algae spend the greater part of their lives in a haploid stage as gametophytes.
- Examples: Sea grapes (Local Name: Nama); Eucheuma (Local Name: Lumi); Nori (Used in Making Sushi)

Eucheuma (Lumi)

Source: *www.bulasamantha.wordpress.com*

Sea-grapes (Nama)

Source: *www.haisansachphanthiet.com*

Nori

Source: *www.brokeassgourmet.com & www.imagebasket.net*

2. BRYOPHYTES (Greek: bryo= moss; phyta= algae)

- First terrestrial plants.
- Lack true roots, stem and leaves.
- No vascular tissues (xylem and phloem).
- Male gametophyte known as **antheridia** produces male gametes (sperms) and female gametophyte known as **archegonia** produces female gametes (eggs).
- Male gametes require water to swim to female gametes.
- Due to lack of vascular bundles and the requirement of water to complete reproduction, bryophytes are low-lying (small) plants and restricted to moist habitats.
- The **dominant** stage in a bryophyte is the **gametophyte**, that is, most of its life is spent in haploid stage.
- Examples: Mosses, Liverworts and Hornworts

Moss

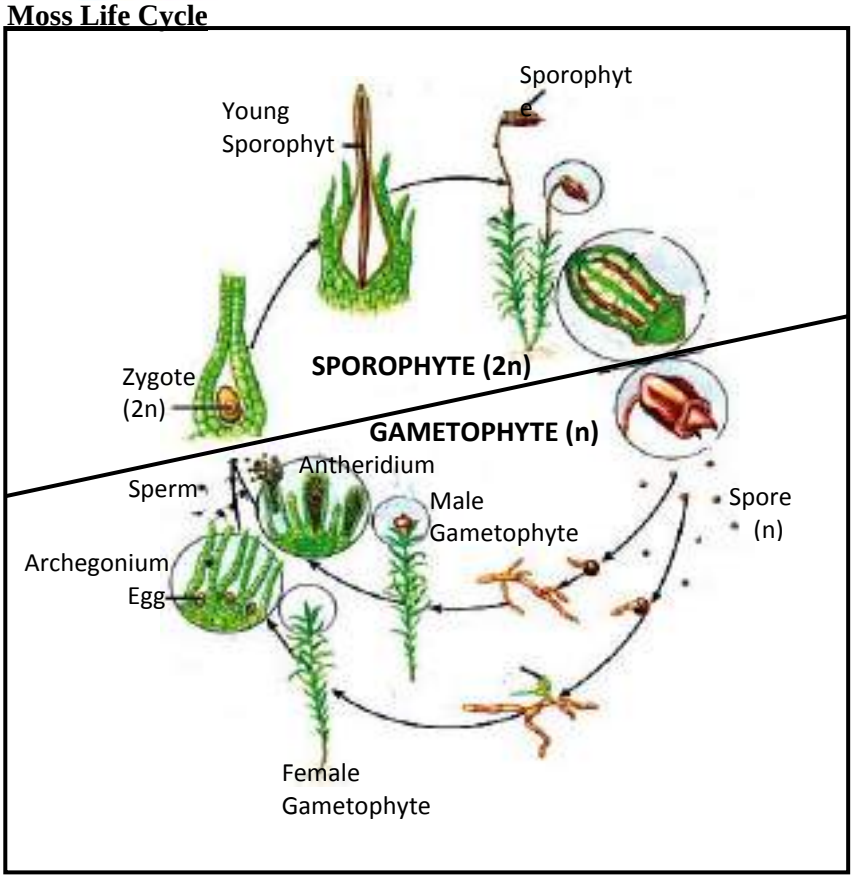
Liverwort

Source: *www.saburchill.com*

Hornwort

Source: *www.ucmp.berkeley.edu*

Moss Life Cycle



Source: *www.molecularecologist.com*

STEPS:

1. The haploid reproductive cells divide by mitosis to produce gametes.
2. Male gametes swim to female gametes.
3. Fertilisation forms a diploid zygote which grows into a sporophyte. The sporophyte lives on the leafy gametophyte.
4. Cells inside the sporophytes divide by meiosis to produce haploid spores.
5. Wind scatters the spores, which will grow into new haploid moss plants.

SPORE vs. SEEDS

	SPORE	SEEDS
SIZE	▪ Small	▪ Large
PLOIDY	▪ Haploid (n)	▪ Diploid (2n)
STORED FOOD	▪ Less	▪ More
PROTECTION	▪ Not much protected from dehydration	▪ Well protected from dehydration (seed coat)
DISPERSAL	▪ Mostly wind	▪ Wind, water, animals
COMPLEXITY	▪ Unicellular (one cell)	▪ Multicellular (many cells)

3. FERNS

- First vascular plants- have xylem tissue for water transport and phloem for food transport.
- Seedless, reproduction using spores.
- Lack true roots, stem and leaves.
- Presence of vascular tissue enables it to grow taller than the bryophytes.
- Male gametophyte- **antheridia**; Female gametophyte- **archegonia**.
- Water/moisture still required for the male gametes to swim to the female gametes; therefore ferns grow in shady areas.
- Dominant stage is the sporophyte, that is, most of the life spent in diploid state.

❖ Examples: *Athyrium esculentum* (Local Name: Ota); Black Tree Fern (Local Name: Balabala); Equisetum; Lycopodium; Pyrrosia; Selaginella

Ota Fern

Source: *www.bulaislandfood.com*

Black Tree Fern (balabala)

Source: *http://collections.tepapa.govt..nz*

Lycopodium

Source: *www.typicalgardener.wordpress.com*

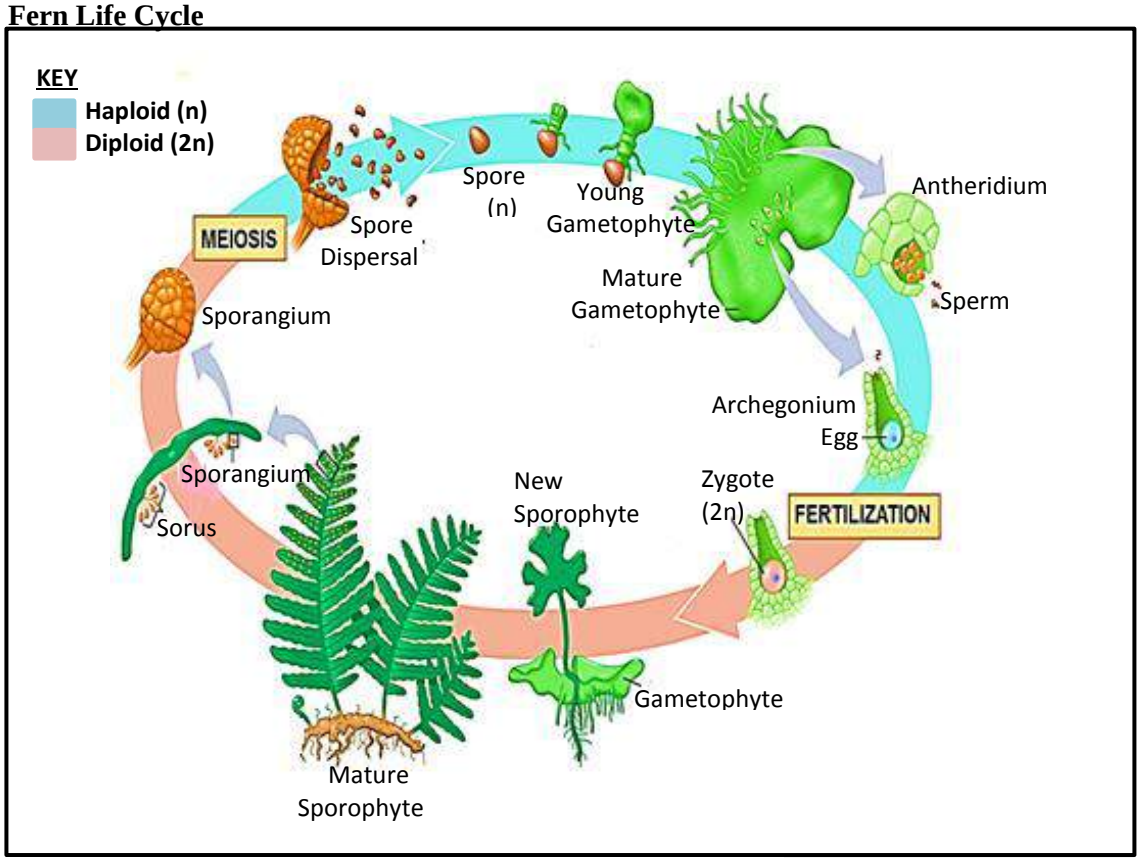
Equisetum

Source: *www.gobotany.newenglandwild.org*

Selaginella

Source: *www.cloudjungle.com*

Fern Life Cycle



Source: *www.studyblue.com*

STEPS:

1. Ferns produce haploid spores by meiosis.
2. Wind scatters the spores.
3. Under the right conditions, a spore divides mitotically to form a tiny, heart-shaped gametophyte.
4. The gametophytes produce eggs and sperms.
5. Fertilisation produces a diploid zygote that grows into an adult sporophyte fern, beginning the cycle again.

SEED PLANTS

- Seed plants evolved with a solution for terrestrial reproduction.
- Seed plants do not require water for the sperm/pollen/male gametes to travel to the egg/ovule/female gametes.
- Seed plants spend their entire life in a sporophyte stage.
- The only gametophyte stage is the sperm and eggs which are haploid.
- The two major groups of seed plants are: **Gymnosperms** and **Angiosperms**.
- Gymnosperms and Angiosperms have slightly different methods of reproduction and seed dispersal.

4. GYMNOSPERMS (Latin: Gymno= naked; Sperms= Seeds)

- First seed plants.
- Have vascular tissues (xylem and phloem).
- As the name suggests, these plants produce 'naked seeds'– seeds not enclosed in a fruit.
- Seeds produced on cones and lay open on the scales of female cone.
- Small male cones produce many haploid pollen grains.
- Dispersal of pollen is via wind.
- When pollens reach the ovules at the tips of the scales of female cones, fertilization occurs.
- Fertilisation forms diploid seeds.
- Seed coats protect the embryos.
- Tissues of the female gametophyte nourish them.
- When seed falls onto warm, moist ground, it grows into a diploid (sporophyte) adult.
- The sporophyte, when mature, makes gametophyte producing cones and repeats the cycle.
- Examples: Conifers (Pines, Christmas trees); Cycads (Sago palms: Local Name: Sago, Sogo, Seko); Ginkgo

Pines

Pine Cones

Source:*www.riosevergreens.com*

Cycads

Source: *www.arkive.org*

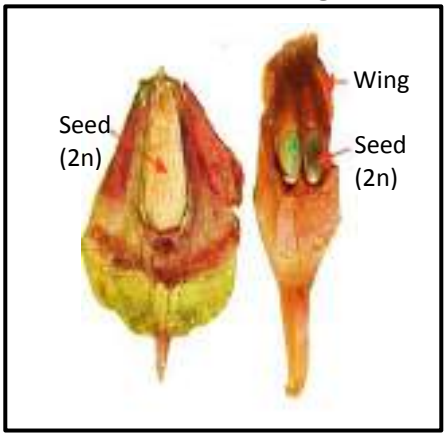
Cycad (Sago Palm)

Source: *www.htbg.com*

Ginkgo

Source:*www.bhort.bh.cornell.edu*

Section of Cones showing Seeds



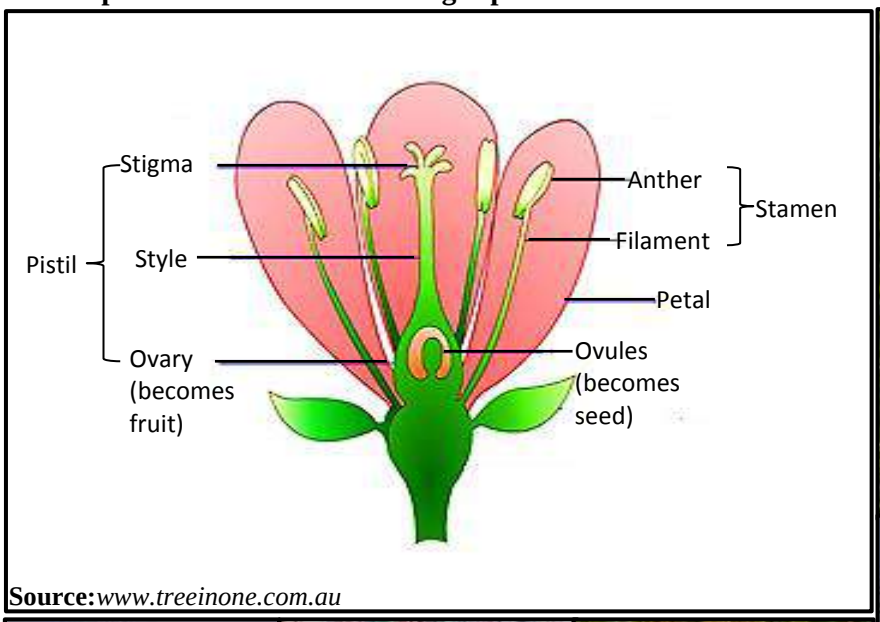
Source:*www.waynesword.palomar.edu*

5. ANGIOSPERMS (Greek: Angion = vessels; Sperms= Seeds)

- Most successful of all terrestrial plants
- Have vascular tissues (xylem and phloem).
- There are several adaptations which make angiosperms so successful.
- Male and female gametophytes reproduced in flowers.
- Male gametophyte is known as **Stamen** (made of anther and filament). Anther produces the male gametes- pollen grains.
- Female gametophyte is known as **Pistil** (made of stigma, style and ovary). Ovary produces the male gametes- pollen grains.
- When an ovule gets fertilized by a pollen grain, a diploid seed forms.
- **Double fertilisation** in angiosperms is a complex phenomenon. In this process, one sperm fertilizes the egg to produce the diploid zygote and the second sperm unites with the two polar nuclei of the central mega gametophyte (female gametophyte) to form the triploid (3n) tissue which later develops into an endosperm.
- The ovary become the fruit and protects the seeds.

- A seed is has 3 parts: (1) plant embryo; (2) a seed coat and (3) a nourishing endosperm.
- Most angiosperms use animals to **cross pollinate** their flowers, rather than depending on wind pollination.
- Angiosperms disperse their seeds using: wind; water and animals.
- Examples: Coconut trees; hibiscus plants; bread fruit trees; and all flowering plants.

The Reproductive Structure in Angiosperms: Flower



Source:*www.treeinone.com.au*

Source:*www.ntbg.org*

SUMMARY TABLE FOR TRENDS SEEN IN PLANT EVOLUTION					
	Aquatic	**Terrestrial**			
	Algae	**Bryophytes**	**Ferns**	**Gymnosperms**	**Angiosperms**
Example	▪ Sea grapes (Nama) ▪ Lumi ▪ Green, Red & Brown seaweed	▪ Moss ▪ Liverworts ▪ Hornworts	▪ Ota ▪ Balabala ▪ Equisetum	▪ Conifers- pines ▪ Sago palms	▪ All flowering plants and trees
Habitat	▪ Ocean, sea, river, drains, ponds, creeks	▪ Moist, shady area on land	▪ Shady areas on land	▪ All terrestrial habitats	▪ All terrestrial habitats
Sporophyte (2n)	▪ Looks similar to gametophyte ▪ Body known as thallus ▪ No true roots, stems or leaves ▪ Not dominant- not long lived	▪ Stalk with sporangium on top of gametophyte ▪ Not dominant- not long lived (**Note**: bryophytes do not have true leaves, stems and roots)	▪ Structure that looks like leaf, stem and roots. ▪ Dominant- long lived (**Note**: ferns do not have true leaves, stems and roots)	▪ Leaves, stems, branches, roots. ▪ Dominant- long lived	▪ Leaves, stems, branches, roots. ▪ Dominant- long lived
Gametophyte **Male** **Female**	▪ Dominant ▪ Thallus has male and female gametophytes (no specific name given)	▪ Dominant ▪ Antheridia ▪ Archegonia	▪ Not dominant ▪ Antheridia ▪ Archegonia	▪ Not dominant ▪ Male cones (small) ▪ Female cones (large)	▪ Not dominant ▪ Stamen ▪ Pistil
Water required for reproduction	▪ Yes	▪ Yes	▪ Yes	▪ No	▪ No
Vascular Tissues	▪ Not present	▪ Not Present	▪ Present	▪ Present	▪ Present
Spore/seed	▪ Spores	▪ Spores	▪ Spores	▪ Naked Seeds	▪ Seeds

PROTISTS &ANIMALS: EVOLUTIONARY TRENDS IN REPRODUCTION

- Simple animals are capable of asexual reproduction.

- They reproduce by:

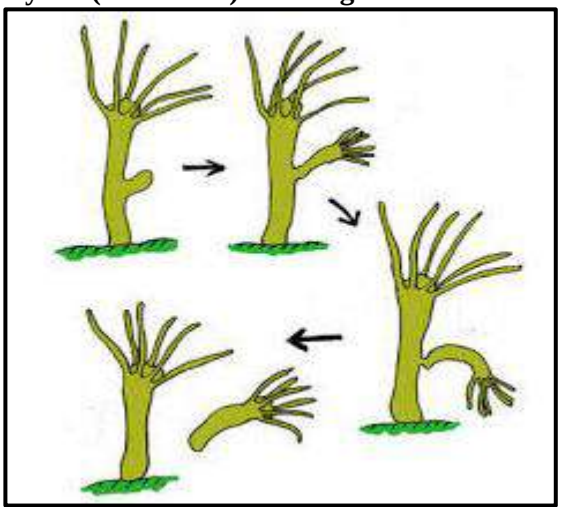
(1) **Fragmentation**- breaking off pieces of their bodies which grow into new individuals. Example: Sponges, Flatworms and Sea stars

(2) **Budding**– where new individuals bud off from their bodies. Example: Hydra

(3) **Regeneration**- modified form of fragmentation. It is the natural ability of organisms to replace worn out parts, repair or renew damaged or lost parts of the body, or the whole body from a small fragment/piece of the body. Example: Sea stars and Flatworms.

(4) **Binary Fission**-separation of the body into two new bodies. The organism duplicates its genetic material and then divides into two parts with each new organism receiving one copy of DNA. Example: Protists- Amoeba, Euglena and Paramecium. Animals- Tapeworms

Hydra (Cnidarian) Budding

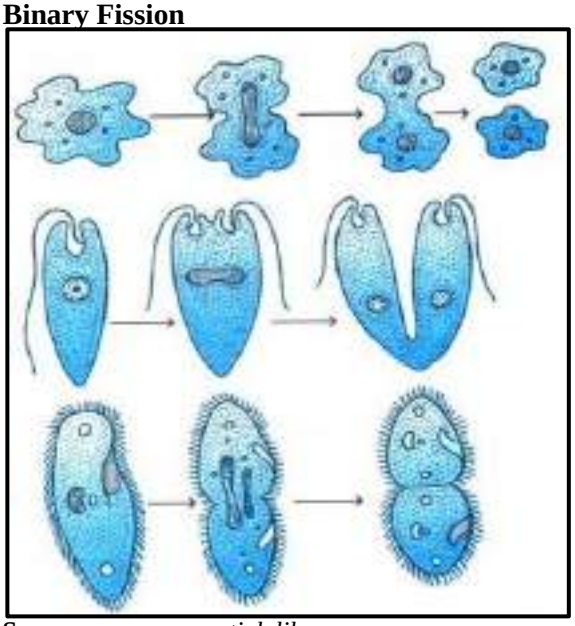


Source: *www.taxawiki1314.wikispaces.com*

Echinoderm Fragmenting

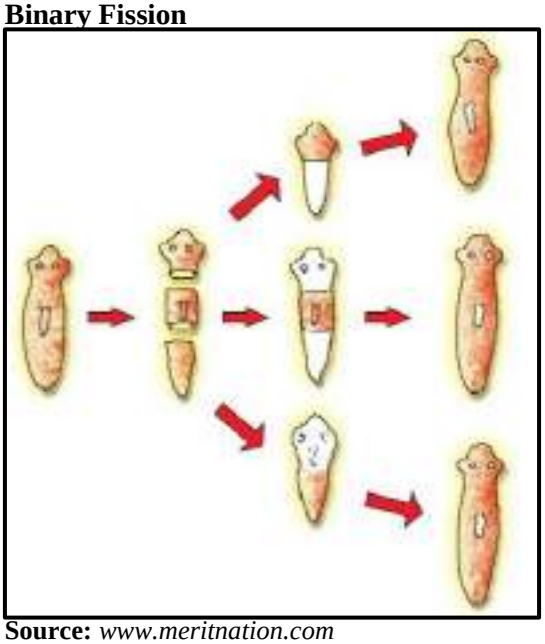
Source:*www.gettyimages.com/photos/common-starfish*

Binary Fission



Source: *www.yourarticlelibrary.com*

Binary Fission



Source: *www.meritnation.com*

- Complex animals are **only** capable of sexual **reproduction.**
- Evolution shows trends towards terrestrial reproduction, fewer offspring and parental care.
- There are different strategies for sexual reproduction amongst animals such as:
  (1) **External fertilisation**–male gametes fertilise (fuse with) the female gametes outside the body.
  (2) **Internal fertilisation**-male gametes fertilise (fuse with) the female gametes inside the body.
  (3) **External development**- the embryo develops outside the mother's body.
  (4) **Internal Development** - the embryo develops inside the mother's body.
- Examples of such animals are: arthropods and vertebrates.

1. External Fertilisation

- Fertilisation occurs outside the body.
- The male and female parents release their gametes into surrounding water.
- The sperms swim to the eggs and then fertilises it outside the female's body.
- The parents do not have sexual intercourse.
- Examples: most fish, sea worms (*Balolo*) and all amphibians.

Limitations of External Fertilisation

1. Eggs and sperms released in water may not meet and therefore gametes and the energy invested in producing those gametes will be wasted. This problem solved by species staying close together when releasing gametes.
2. This type of fertilisation can occur only in water. Not a problem for fish but for amphibians, they have to go from land to aquatic environment.
3. Eggs released are soft and therefore vulnerable to predation. Therefore numerous eggs are laid to ensure that at least a few offspring will survive. Predators eat most of the offspring either at the egg stage or soon after hatching.

Salmon Fish Eggs

Source: *www.marinebio.net*

Frogs releasing gametes

Source: *www.cathylaw.com*

Female Sea worm releasing eggs

Source: *http://seapics.com*

2. Internal Fertilisation

- Fertilisation occurs inside the body.
- The male deposits his sperm inside the female.
- Such fertilization involves sexual intercourse.
- The sperm swims to the eggs inside the female's body.
- For this type of fertilisation, water is not a requirement and therefore fertilisation can occur in terrestrial (land) environment.
- Since, fertilization is internal; fewer gametes are produced to prevent wasting of energy in producing those gametes.
- Examples: Insects, reptiles, birds and mammals all fertilise their eggs internally.

3. External Development

- The **embryo** develops outside the mother's body.
- With external fertilisation, development of embryo is automatically external.
- With internal fertilisation, development can either be external or internal.
- After internal fertilization; some animals lay their eggs and the embryos develop externally.
- Example: Some insects, some fish, reptiles and birds develop externally.
- The egg contains a yolk, which provides nutrients for the developing embryo.
- The yellow part of a chicken egg is the yolk, meant to provide food for the embryo in case the egg is fertilized.
- Eggs of terrestrial animals have **hard** shells to protect the embryo from the dehydration.
- Reptile egg shells are not hard; instead it is **flexible** but are still **tough** and **leathery** to prevent dehydration.
- The aquatic animals' eggs have a **jelly-like coating** because dehydration is not a problem for these eggs.

Disadvantage of External Development

- Embryo extremely vulnerable to predators.

Hard-Shelled Eggs of Birds

Flexible Eggs of Turtles

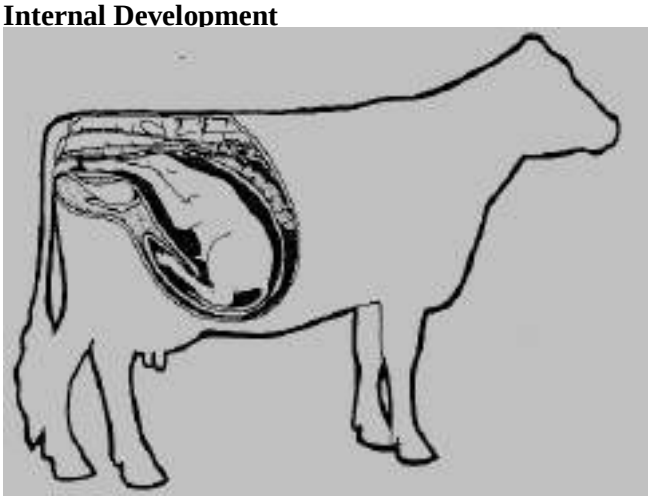
Source: *www.en.citizendium.org*

RESEARCH WORK

- Identify how the following animals that lay eggs protect it from being eaten:
  - turtles
  - birds (chicken, pigeons, doves)
  - insects (cockroaches, caterpillars, bees)

4. Internal Development

Internal Development



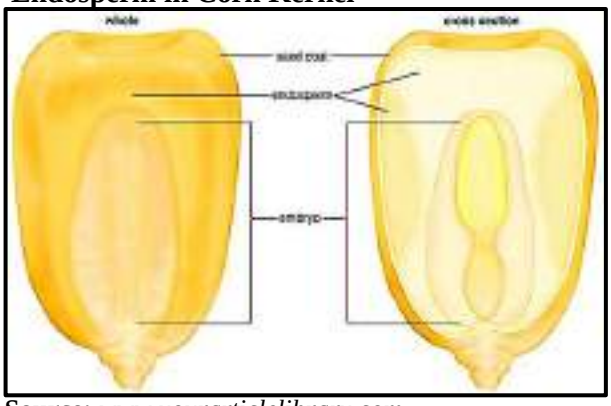
Source: *www.nongae.gsnu.ac.kr*

- ❖ Embryo develops and is protected and nourished inside the mother's body.
- ❖ Internal development provides the protection to the developing embryo from predators.
- ❖ Only mammals have true internal development where the developing embryo is nourished via mother's blood.
- ❖ Few species of reptiles and fish keep their eggs inside their bodies until the eggs hatch. The mothers then give birth to live offspring but the developing embryo is nourished for by the egg yolks and not the nutrients from the mother's bloodstream.
- ❖ Example: Sharks and Rays. The eggs nourish the developing embryo and it hatches inside the mother's body. Baby sharks and rays are given birth to.

Reproductive Success in Plants

Some of the reproductive successes in plants are attributed to:

Endosperm in Corn Kernel



Source: *www.yourarticlelibrary.com*

1. **Double fertilization**- double fertilization in angiosperms leads to formation of endosperm which provides nourishment to the developing embryo.

2. **Seed Dormancy**- a mechanism to prevent germination during unsuitable ecological conditions, when the probability of seedling survival is low. Seeds delayed germination allows time for dispersal and prevents germination of all the seeds at the same time (reduces competition and ensures viability).

3. **Dispersal Methods**- is the movement or transport of seeds away from the parent plant via wind, water and animals. Dispersal methods contribute to reproductive success by:
   - High chances of seed survival when away from the parent plant. Competition with adult plants may also be lower when seeds are transported away from their parent.
   - Allowing plants to reach specific habitats that are favourable for survival.
   - Allowing seeds to avoid adverse environmental effects such as fire or drought.
   - Allowing plants to colonize vacant habitats and even new geographic regions.

Reproductive Success in Animals

Some of the reproductive successes in animals are attributed to:

1. **Parental Care**- is the investment a parent will put into their offspring, which includes protecting and feeding the young, preparing burrows or nests, and providing eggs with yolk. With evolution of higher animals, the trend observed was lesser number of offspring. Having fewer off springs allowed parents to invest in parental care which encouraged the survival and possible reproductive success of the offspring.

Courtship Behaviour displayed in peacock

Source: *www.buzzle.com*

2. **Courtship Behaviour**- behaviour by which animals select their partners for reproduction. Mostly, the male initiates the courtship, and the female chooses to either mate or reject, based on his "performance". Many animals have mate-selection courtship rituals. Displays are performed by animals seeking to advertise their willingness to mate, attract a partner and sometimes to warn off rivals.
   Example: display of a male peacock's tail, and elaborate dancing.

3. **Pair Bonding**- forming a close relationship through courtship and sexual activity leading to production of offspring and/or a lifelong bond.
   Example: Social and sexual pair-bonding is observed in some human relationships. Other animals which form strong pair bonds are: gibbons, swans, black vultures, wolves, termites and penguins.

Pair Bonding in Gibbons

Source: *http://www.mnn.com*

4. **Territorial Behaviour**- when animals actively defend their territory for food, shelter and mate. Territorial behaviour ensures availability of mates and also display of such behaviour by males help attract the females (females are usually attracted towards strong, dominant, powerful males).
   Example: When dogs urinate (pee) in their surrounding; they are sending signals to other dogs that it is their territory.

SELF TEST

1. Explain why female humans produce only two eggs per month whereas female frogs produce thousands of eggs?

2. Turtles and cattle both have internal fertilization but turtles can have as many as fifty to hundred or even more off springs per reproductive cycle whereas cattle can have only a maximum of one or two. Explain why?

3. Explain the trend observed for the sporophyte and gametophyte in plants as they moved from aquatic environment to terrestrial environment.

4. Differentiate a spore from a seed. How is a seed better adapted for life on land?

5. Identify plant groups that require water for reproduction.

6. Read the following descriptions of the life cycles of different plants. State the group to which each plant belongs.

a. This plant spends almost its entire life in a sporophyte stage and produces fruits.
b. These terrestrial plants spend most of its life as a gametophyte.
c. These plants produce and protect gametes in a flower.
d. Plant produces naked seeds.
e. Terrestrial plant which is seedless, lack true roots, stems and leaves but has vascular tissues.
f. These plants produce seeds on cones.

7. Identify the difference between a snake's egg and a Parrot's egg.

8. Explain the difference of how the developing embryo is nourished in lizards and in bats? (Hint: bats are mammals).

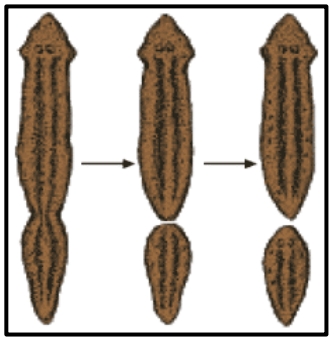
9. Describe one advantage and disadvantage of investing parental care in offspring.

10. Birds have to sit on their eggs until it hatches to keep their embryos warm.

a. Explain how placental mammals have overcome this problem?
b. Identify a reason why birds cannot adopt the technique used by the placental mammals.
c. Explain why turtles don't have to sit on their eggs until it hatches? (Hint: something to do with their blood)

11. Use the diagram to answer the following questions:

a. Identify the type of reproduction that is occurring in the flatworm.
b. Explain how such type of reproduction is advantageous to simple organisms like flatworms.
c. Explain why such reproduction is not suitable for higher animals like mammals.



Source:*www.glencoe.mheducation.com*

12. In vertebrates, what stage of life is haploid?

13. For each of the following organisms, state whether the animal has external or internal fertilisation and external or internal development:
parrotfish, snake, toad, rat, dolphin, mosquito, human, and bulbul.

14. How do bacteria cells reproduce?

15. What is the purpose off egg yolk?

16. Describe one advantage and disadvantage of investing parental care in offspring.

17. Describe the parental care that each of the following animals provide to their offspring:
mynahs, white flies, toads, cows, humans, sea turtles.

18. A sea star may lay millions of eggs in its lifetime. Why don't the seas fill with sea stars?

19. Why do all terrestrial animals fertilise their eggs internally?

20. Describe two problems associated with external development on land.

STRAND 2

YEAR 12

SUB-STRAND 2.1

ORGANISM AND THE ENVIRONMENT

SUB-STRAND 2.1: ORGANISM AND THE ENVIRONMENT

ACHIEVEMENT INDICATORS

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

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

- ✓ Examine and explain the stages a population goes through as it increases in size.
- ✓ Analyse the structure of a population in terms age distribution.
- ✓ Differentiate between density dependent and density independent factors.
- ✓ Discuss the factors that limit the population growth.
- ✓ Investigate by carrying out field studies to illustrate the different community patterns.
- ✓ Study and explain some examples of community periodicity shown by plants and animals.

BI 12.2.1.1 POPULATION

Ecology is the study of the interactions of organisms with one another and with their environment. In year 11, the ecological interaction at three levels studied were:

- **Population** - a group of organisms of one species living together in an area at a given period of time.
- **Community** - all the populations of organisms living in an area.
- **Ecosystems** - a community and its environment. In the study of ecosystems, we consider organisms' relationship with one another and with their physical environment.

This year we further explore the patterns in populations and communities.

Population ecology is the study of populations in relation to the environment, including environmental influences on population density and distribution, age structure, and population size.

The features used to describe a population are:

Population size

- Population size refers to the number of individuals in a population.
- Letter '**N**' is used to indicate the population size.
- Thus, if there are 12 dogs that live within your school compound, then the population of dogs in your school compound is, N = 12 dogs.
- The units of the population are the population being counted.

Population range:

- Refers to the area within which the population is found.
- In the example of dogs given above, the range would be the area of your school compound.
- Since range is an area, the units of the range will be either km^2 or m^2.

Population density: refers to the number of individuals which may be present in each unit area.

$$\text{Population density} = \frac{\text{Number of individuals (N)}}{\text{Population range}}$$

For example, if there are 400 pine trees in an area of 2 km in length and 100 km in width then the population density of pine treees would be:

Number of individuals = 400
Population Range = 2 km x 100 km = $200km^2$

$$\text{Population density} = \frac{400}{200}$$

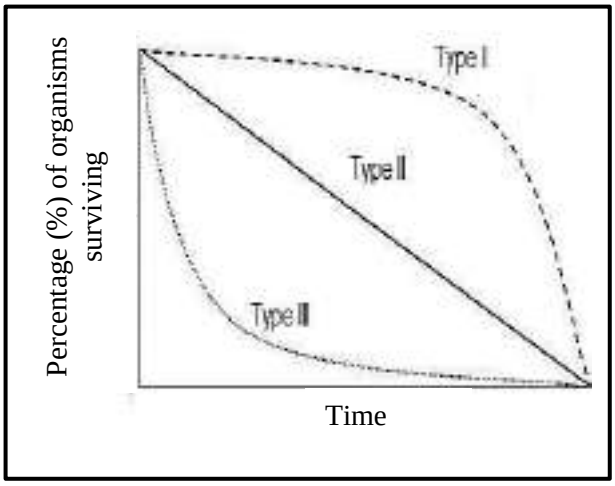
$$= \mathbf{2\ trees\ /\ km^2}$$

❖ Within any population, one will find individuals of varying ages. These are two factors that control the age structure of any population;

i) Natality or birth rate
ii) Mortality or death rate

- Some organisms have a very high death rate because they live in areas where conditions are not favourable or they have plenty predators or enemies e.g. mice.
- These types of organisms make up for the high moratality rate by having an equally high natality rate.
- Generally, species that show high parental care (mammals and some birds) live longer than those with no or little parental care e.g. toads and frogs.
- Those organisms that show high parental care make up by producing very large numbers of gametes during reproduction.

Survivorship curves: are useful ways of showing the mortality and natality rate for different populations. Survivorship curve is the 'chance of remaining alive'. There are three types of survivorship curves:



Source: https://en.wikipedia.org/wiki/Survivorship_curve

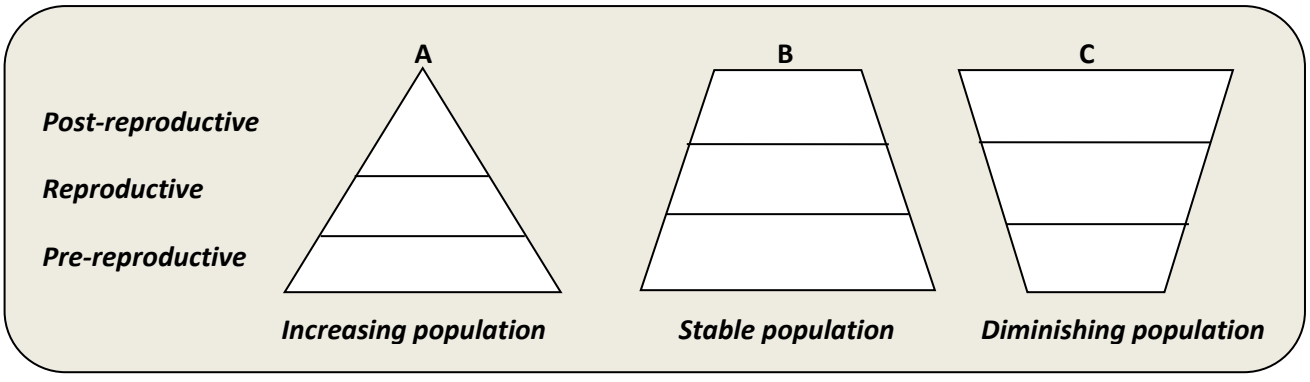
Type I - mortality is low at youth, many individuals survive to reach an old age e.g. humans.

Type II - there is equal chance of dying at any time in life. e.g. insects. Their mortality rate is constant throughout their lives.

Type III - many individuals die at a young age e.g. fish. Their mortality rate is high in the juvenile stage.

Age pyramids

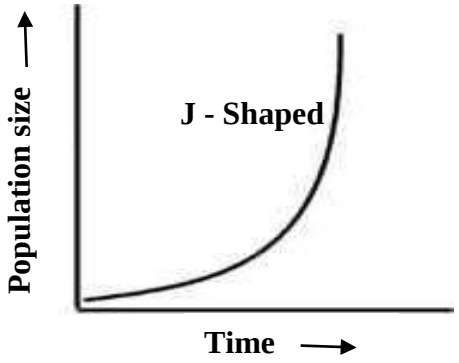
- Show information about the number of organisms of a particular age group that is alive in a population.
- This can be used to decide whether the population is increasing or decreasing.
- Generally, the breath or width of the pyramid indicates the number of organisms in that age group.
- There are three distinct age pyramids that can be identified.



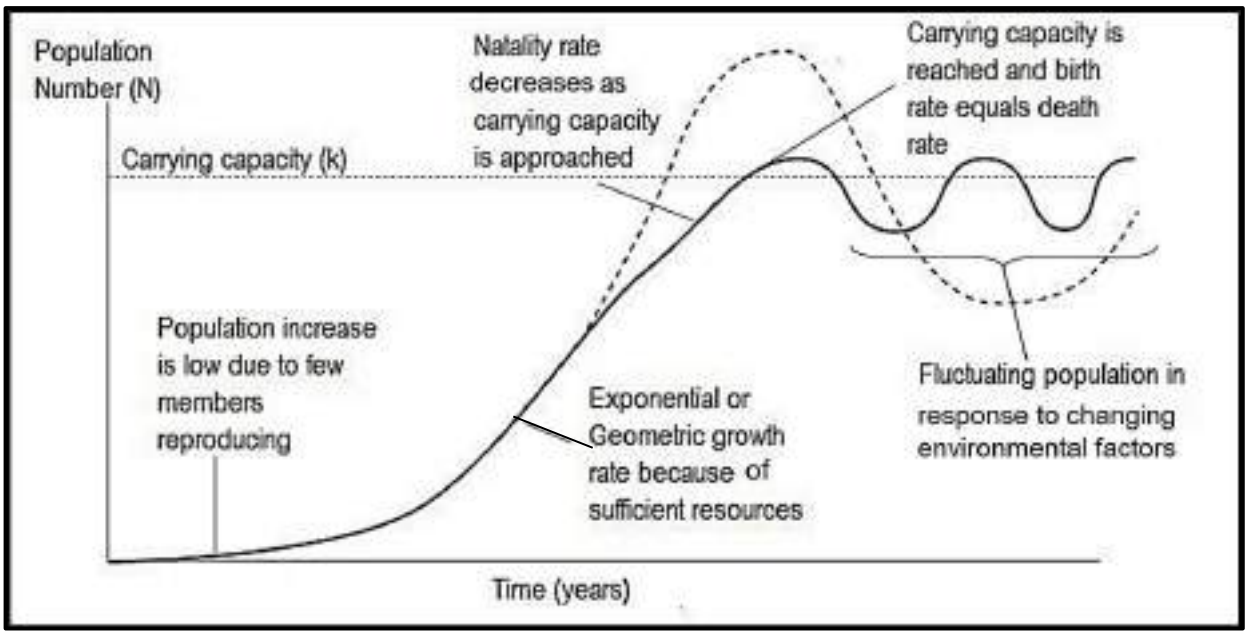
Carrying capacity

- Is the maximum size that can be supported indefinitely by the available resources in the environment in which they live.
- The carrying capacity is designated by the letter '**k**'.
- When the population size exceeds the carrying capacity, the population size (N) of the population will decrease as animals move to new habitats or die of starvation because the resources are over-exploited.

Population Growth



- When a species is placed in a new environment where there are sufficient resources, the growth of its population will be representative of an exponential or **J- shaped curve** as shown.
- The population increases rapidly because resources are abundant.
- A population however, cannot keep growing as in the J-shaped graph because resources will become depleted and the N will start to decrease.
- A more realistic graph of natural population growth rate is shown below in the **s-shaped curve** or a **sigmoid curve**.



Population Dynamics

- ❖ Members of a population:
  - rely on the same resources.
  - are influenced by similar environmental factors.
  - have a high likelihood of interacting with and breeding with one another.

- ❖ Populations can evolve through natural selection acting on heritable variations among individuals and changing the frequencies of various traits over time.

Limitations of a Population

- Populations tend to grow and also shrink with time.
- An example of population that is increasing continually is the human population while a population which is shrinking is the turtle population.
- The growth and shrinkage of a population is controlled by many factors.
- Two such factors are: **Abiotic Factors** and **Biotic Factors.**

Abiotic Factors

- Abiotic factors are physical conditions or the non-living part of the ecosystem.
- Examples of abiotic factors include light, temperature, rainfall, atmospheric gases, wind, mineral levels, humidity, soil etc., and earthquakes, floods, volcanic eruptions and storms which have more catastrophic effects on populations.
- Plants and animals depend on abiotic factors for growth and other processes.
- Abiotic factors affect a population regardless of the density of the population and are therefore, said to be **density-independent.**

Biotic Factors

- **Biotic factor** is any activity of a living organism that affects another living organism within its environment.
- Biotic factors within a community can affect the populations of organisms but are also essential to the balance of life within the ecosystem.
- Examples of biotic factors include competition, parasitism, predation, diseases and toxic waste.
- These factors are **density-dependent** and usually affect a population in a predictable fashion.

Density – dependent Population Regulation

Competition

Source: www.pinterest.com

- Competition for resources increases as the population increases due to members of the population (members of the same species) having identical resource needs.
- Producers compete for light, space, water, minerals and substrate.
- Consumers compete for space water shelter, breeding sites and food.
- Intraspecific competition strongly regulates population size by favouring the stronger and more adaptable individuals who are able to obtain most of the resources.
- Interspecific competition also keeps a population's size lower due competition for similar resources between different species.
- Interspecific competition can be detected by removing one species, if the population of the remaining species increases, the two species must have been competing for the same resources (Gauze's Principle of competitive exclusion).

Parasitism and Disease

Source: http://www.todayifoundout.com/

- Parasites and pathogens spread rapidly in a dense population.
- When a pathogen first spreads, both pathogen and host populations usually drop rapidly.
- The most lethal strains of the pathogen and the least resistant hosts die out.
- Eventually, the host and pathogen achieve equilibrium.
- Since the host population supports additional organisms (the pathogens or parasites) with the same amount of resources, the host population size usually is smaller than before infection.

Predation

Source: http://www.npr.org/

- Predators often have a good effect upon a prey population, preventing it from over – exploiting its habitat.
- Predator and prey population sizes tend to fluctuate together.
- If a prey population increases their predators have more to eat and so eventually the predator population also increases.
- This shrinks their food supply and, eventually their own population.

Toxic Waste

Source: http://www.earthuntouched.com

- Natural waste production limits populations, e.g., the mould *Penicillium* produces penicillin which kills bacteria.
- Algal blooms produce toxic compounds that can kill fish.
- Toxic wastes within a population can limit the population itself, e.g., alcohol produced by yeasts limits yeast production.
- Humans produce toxic waste from sewage and industry.
- This pollution can kill many life forms.

Density- Independent Regulation of Growth

- Any factor that regulates a population's size in a way unrelated to its density is called a **density-independent** factor.
- Natural disasters and sudden environmental change often kill entire populations of organisms, regardless of their density.
- For example, if a fire sweeps through a field, it will kill other small organisms also living in that field.
- Floods, fires, droughts, frosts and cyclones regulate population size independent of population density.

Human Threat to Populations

- Human population's growth threatens the survival of many wild animal populations independent of their densities.
- Hunting has reduced whale, tuna and hundreds of other animal population to dangerously low numbers.
- Additionally, habitat loss to farms and settlements has driven many species to extinction and is pushing still more to the edge.
- Demand for some animal goods such as ivory and turtles shells actually increases as their source populations become dangerously scarce.
- Poaching (illegal hunting) threatens tigers, African elephant, rhinoceroses, pandas and sea turtles with extinction.

Factors that limit population size		
	Factors that increase the population size	**Factors that decrease the population size**
Abiotic	– Favourable light. – Favourable temperature. – Favourable chemical environment.	– Too much or too little light. – Too cold or too warm. – Unfavourable chemical environment.
Biotic	– Sufficient food. – Less predators or ineffective predators. – Few diseases. – Weak parasites. – Ability to compete for resources.	– Insufficient food. – Many effective predators. – Deadly diseases. – Strong parasites. – Inability to strongly compete for resources.

SELF TEST

1. Give two examples of how plants and animals affect their environment.
2. Describe how temperature, light, and soil affect an ecosystem.
3. Which type of survivorship would birds have?
4. Think of a forest ecosystem. Now imagine that a large amount of dust and ash into the air is blocking out sunlight. How might the forest ecosystem be affected if the sunlight is:
   (i) blocked out for a day?
   (ii) blocked for a year?
5. Name three density-dependent threats to the human populations.
6. What can we do to prevent a human population crash?
7. Explain why intraspecific competition is more intense than interspecific competition?
8. Explain how algal bloom is caused in water ways? How this eventually leads to the fish and other aquatic life?
9. Explain why outbreaks of diseases are common post a natural disaster like flooding.

10. The population size of fruit bats in Fiji is regulated by many different factors. For each of the population-regulating factors described below, state whether the factors is density- dependent or density –independent.

a. Cyclone Kina

b. An increase in the number of owls (predatory birds that hunt at night)

c. A bacterial disease

d. Competition for food from other bats

e. A drought

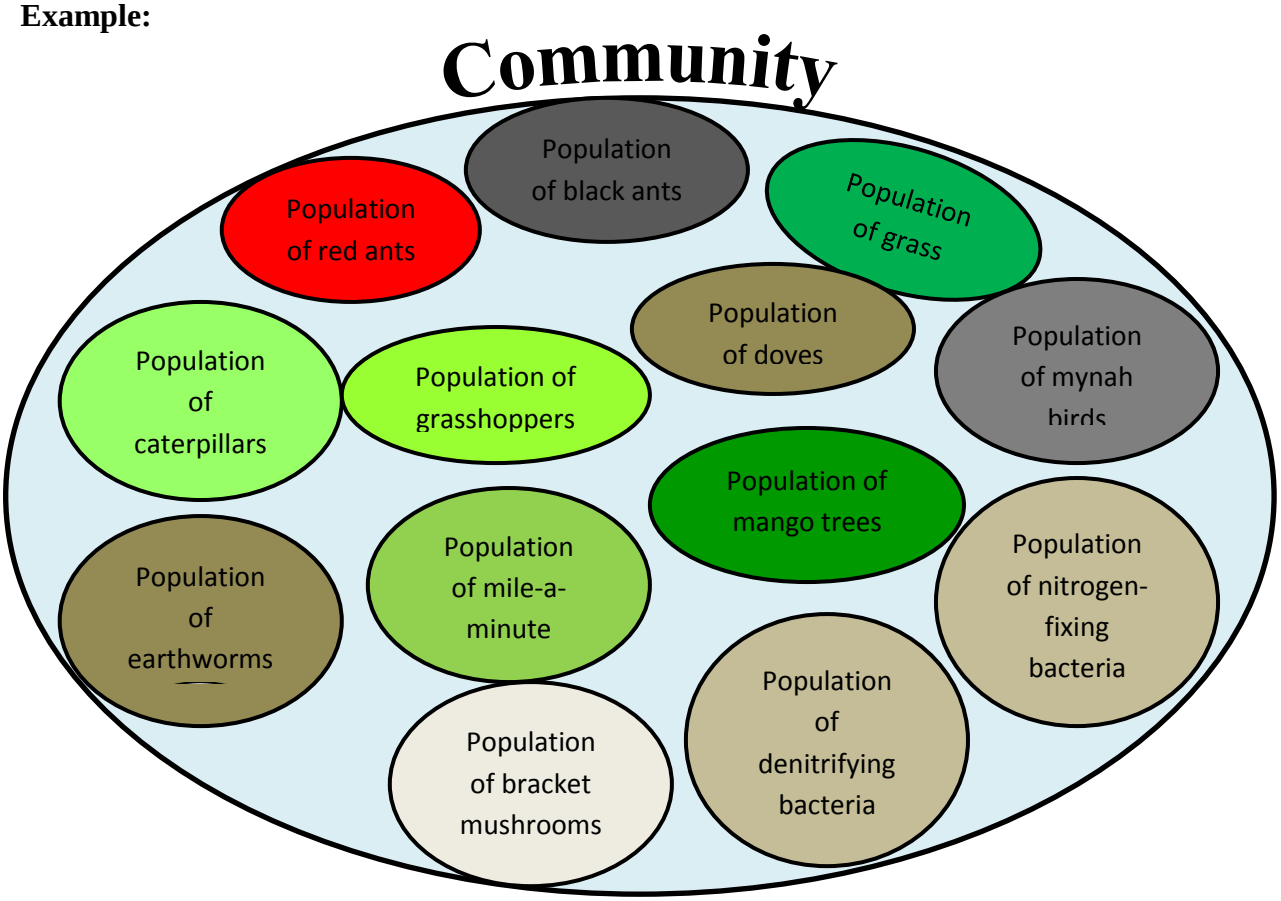
11. In biology, success is defined by the number of surviving offspring an organism produces. However; strains of pathogenic bacteria that reproduce quickly and kill their hosts usually die out. Why?
12. Describe three ways humans have increased the carrying capacity of the earth for our population. How have we decreased it for other populations?
13. Name three density-dependent threats to the human populations.

BI 12.2.1.2 COMMUNITY

Community refers to a group of plant and animal populations that live in a particular area at a particular time and interact with each other. Every member of the community plays a specific role.

Community defers from population in that **population** is made of only one type of species.

Example:



- The above community is made of:
  - Red ants
  - Black ants
  - Caterpillars
  - Grasshoppers
  - Earthworms
  - Mynah birds
  - Doves
  - Denitrifying bacteria
  - Nitrogen-fixing bacteria
  - Grass
  - Mango trees
  - Mile-a-minute (climbers)
  - Bracket mushrooms

- These populations play a specific role in the community and in one way or another, interact with each other.
- The possible types of interaction in a community are:

(1) Competition- interaction that occurs when individuals of different species compete for a same resource which is limited in supply. This limits the growth and survival of organisms involved. Both the organisms involved are affected negatively. (- / -)
Example: Suppose for the above community, if the red ants and the black ants both prefer to eat same type of food; competition for food when limited supply will drive these two species to fight for resources. This will have a negative impact on both the red and the black ants.

Ecological Niche

- Niche (pronounced: nitch) is the ecological role a species plays in its ecosystem.
- It refers to everything about its way of life, particularly its relationship with other organisms and with its physical surroundings (involves both biotic and abiotic factors).
- This includes the organism's energy sources, habitat, water and minerals, climate preferences and reproductive method.
- Example: an organisms habitat is its 'home address' and its ecological niche is its 'profession'.
- For example, an earthworm's niche includes borrowing through the soil eating organic matter. Earthworms prefer a moist, dark habitat, and birds are their main predators. They produce sexually, with internal fertilization, and each individual has both female and male sexual organs.
- Organisms living in the same community **compete** with each other when their **niches overlap**.
- Since competition harms both organisms involved, division of resources is favored by natural selection to reduce the niche overlap between species.
- A division of roles and resources in a community allows a large number of species to live together in the same area.

Examples of Resource Division/ Partitioning

- There are nine different species of fruit-eating pigeons in the rainforests of Papua New Guinea. Why doesn't competition for food drive less competitive species into extinction?

Competition has pushed each pigeon species to evolve adaptations for a slightly different niche. All fruit available in the forests is not the same. Some fruits flow on trees with thin branches, some grow on trees with thick branches. Some fruits are large, some are small. The various body sizes and beak shapes among the different pigeon species adapt them for eating different kind of fruits. The smaller species can land on thin branches that larger pigeons would break. Some species have short thick beaks for cracking nuts, some have hooked beaks for tearing fruit peels while others have sharp beaks for poking through fruit skins. This division of resources reduces competition between the pigeon's species.

Likewise, Fiji has three endemic species of fruit–eating doves. All three eat fruit, insects and caterpillars that they find between the forest undergrowth and tree tops. All three are about the same size and have very similar beaks. With such a large niche overlap, these three species of doves cannot live together. They have survived by spreading across Fiji. The golden dove lives on Viti Levu, Ovalau and Gau while the orange dove makes its home on Vanua Levu and Taveuni and the whistling dove is restricted to the Kadavu and Ono Islands.

Resource division reduces competition, allowing greater population size and diversity in communities. Species that have similar niches share resources in different ways, in different areas, or at different times.

(2) **Predation**- interaction between species in which the predator kills and eats the prey. In this type of interaction, the predator benefits and the prey is negatively affected. (+ / -)
Example: mongoose kills and eats chicken, therefore the mongoose is a predator and the chicken is the prey.

(3) **Herbivory**-interaction in which an organism eats parts of the plant or algae. In this relationship the herbivore benefits and the plant is negatively affected. (+ / -)
Example: when cows eat grass they do not kill the plant entirely. The cow benefits by getting food but the grass is negatively affected because the greens are lost and photosynthesis will be affected.

(4) **Symbiosis** (sym = together; bios = living) - relationship when individuals of two or more species live in direct contact with one another.
Examples of symbiotic relationship are:

- **Amensalism**- relationship where one organism is harmed, the other remains unaffected.(- / 0)
  Example: An algal bloom in the river causes death to so many fish and aquatic animals but the algae in no way benefits from it.

- **Commensalism**- relationship where one organism benefits and the other organism remain unaffected. (+ / 0)
  Example: barnacles which are sessile organisms, sometimes attach themselves to whales. As the whales swim, the water currents bring in food for the barnacles. In this way the barnacles benefit while the whale remains unaffected.

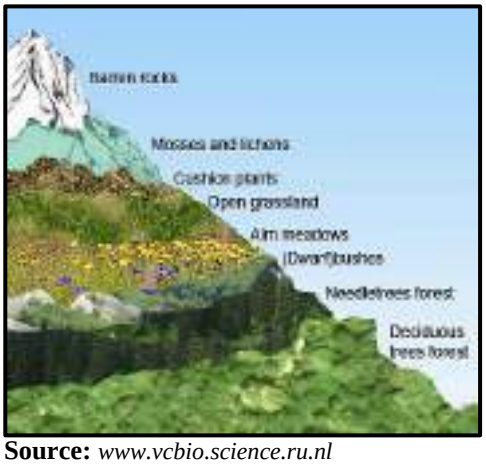
- **Mutualism**- relationship where both organisms benefit. (+ / +)
  Example: humans and their pet dogs. The dog receives food, care and shelter from the owner while the owner receives companionship and protection.

- **Parasitism**- relationship where the parasite benefits and the other host is harmed. (+ / -)
  Example: Neats and lice (Fijian word: kutu and lice), the parasite, living in human hair benefits by obtaining habitat and food (sucking blood). The host (human) on the other hand gets negatively affected because it looks dirty, results in the loss of blood, causes itchiness and sores.

Community Patterns

1. **Zonation**

- The division of organisms into areas, or **zones**, of varying environmental factors is called **zonation.**
- Different species living in different areas/zones of a community **reduces competition** between them.
- Species live in different zones according to their adaptations.
- Zonation is horizontal environmental divisions- side by side.



Source: *www.vcbio.science.ru.nl*

❖ **Example 1**: Next time you go to an undisturbed beach, notice the pattern in which the plants grow from the shoreline. The first type of plants you will notice will be creepers, grass and other low-lying plants. As you walk away from the shore, more to the inland, you will notice plants almost your height and further inland, there will be bigger plants.

> **Research**: Similar to plants, zonation in animals living on the sea-shore can also be observed. When you go to a beach, observe the animals that inhabit the shore. Identify the animals that are found in the different zones.

❖ **Example 2**: The stream ecosystem has roughly three zones; (1) wet zone in the stream, (2) damp zone next to it, (3) and dry zone farther away from it. Different organisms are adapted to the zones conditions. In the stream (wet zone) you will find algae. Near the stream banks (damp zone) you will find ferns and mosses farther away (dry zone) you will find herbaceous plants.

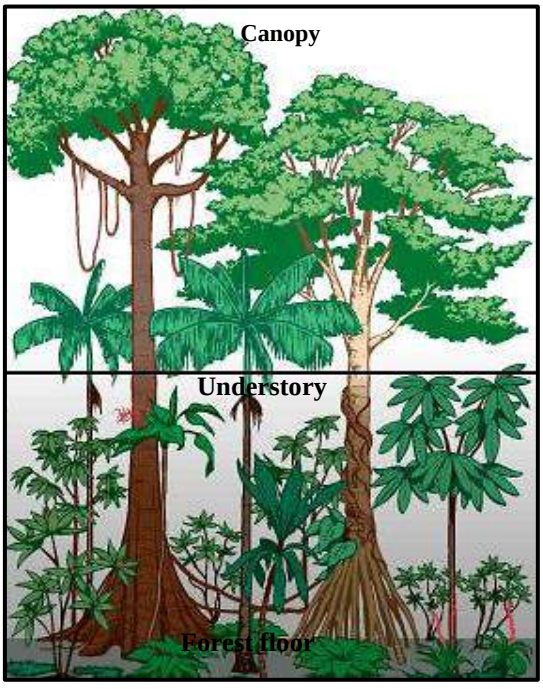
❖ **Example 3**: Zonation also occurs on the sides of high mountains. The environment at the top of high mountains is normally cold, windy and dry. Conditions at the bottom are more moderate.

2. Stratification

- Humidity is the amount of moisture in the air.
- The stickiness you feel in your skin during hot weather is due to humidity.

❖ **Stratification**- vertical layers of organism in communities.
❖ Each layer is known as stratum and different organisms live in the various strata depending on their living requirements.

❖ **Example 1**: Forest communities often show stratification. The top layer of a forest is called the **canopy**. Canopy receives the highest amount of sunlight and wind and the lowest amount of humidity. The middle layer of the forest is known as understory. The amount of sunlight and wind in the understory is less than that in the canopy, but the humidity is high. The bottom layer, that is, the forest floor is the darkest and the most humid layer of the forest.



Source: *https://daac.ornl.gov*

❖ Stratification reduces competition between species in two ways:
(1) It divides the organisms into separate areas, just like zonation.
(2) The many strata create a large number of varied habitats, greatly increasing the diversity and number of organisms the ecosystem can support.
❖ Stratification also occurs in the oceans.

(3) Succession

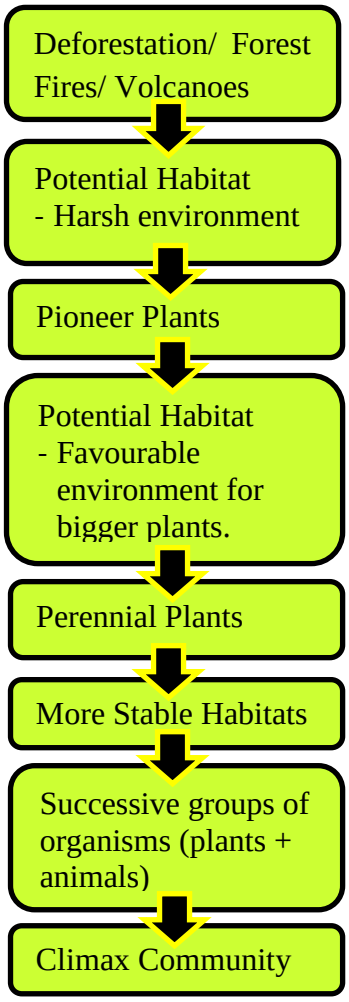
- Succession is the orderly progression of species composition in an empty area of land, from colonizing pioneer species to a stable community.

- Succession occurs in several stages:

1. A new habitat currently with no form of life is created. Example: A new island created by a volcanic eruption; or by a forest fire; or after deforestation.

2. Pioneer species colonize (inhabit) the newly available habitat. As pioneer plants spread over the exposed land, they shelter the soil from the sun, wind and pounding rain. Their roots help prevent erosion. As older plants die and decay, the soil becomes more fertile. Over time, the pioneers create an environment favorable for larger perennial plant whose seedlings require shades, moisture and fertile soil.

Pioneer species
Organisms adapted to growing in exposed, windy areas with intense sunlight, varying temperatures and low fertility soil. Pioneers are usually small, annual plants that produce large numbers of wind dispersed spores or seeds.

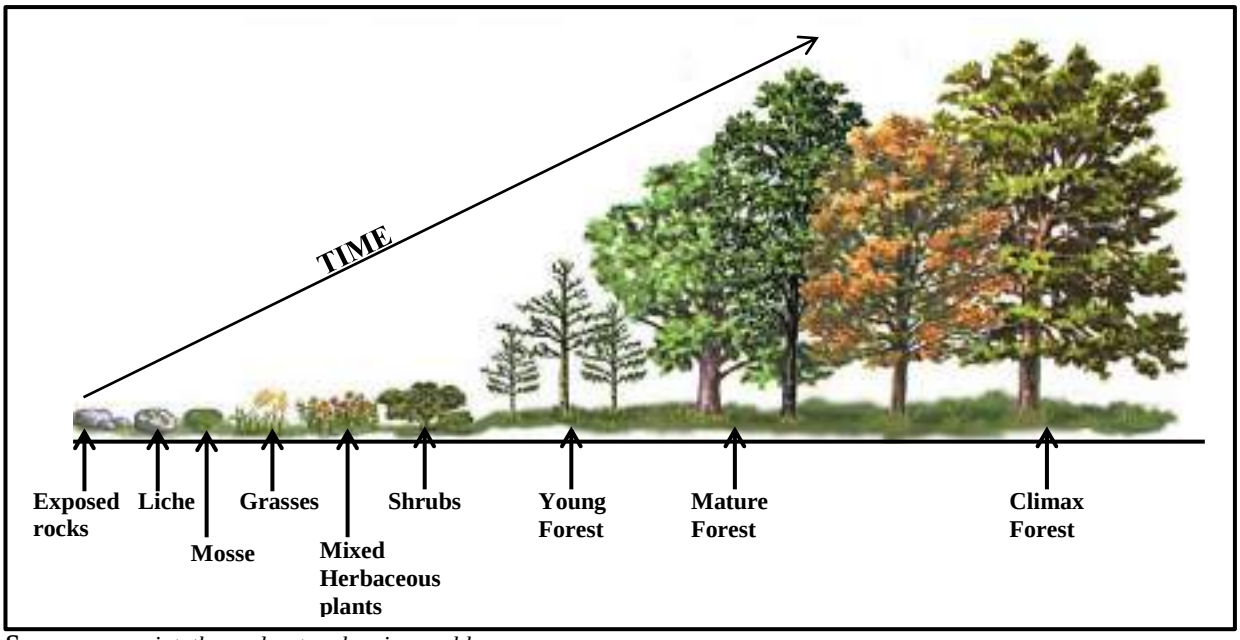


3. Once pioneers have sheltered the soil, the seeds of perennial plants can take root. In moderate habitats, perennials have two competitive advantages over annuals: early growth each year since they live for more than one growing season and a much larger energy store. Over time perennials crowd out the original pioneer species.

4. Eventually, after several stages of successive groups of organisms, the environmental conditions stabilize and the community reaches a stable composition of species called the **climax community**.

- Succession divides resources between different species with respect to time.
- In contrast, zonation and stratification divide resources by space.
- Less dramatic succession occurs after habitat disruptions such as fire, deforestation, bulldozers or even a falling tree. In such cases, the environment is not so harsh and plants grow from seeds or seedling already present. However, one group of species replaces another as environmental conditions change until the community reaches a stable composition of species.
- The time a community takes to reach a climax composition of species varies greatly.
- Simple communities, such as grasslands, need only a few years to return to normal after destruction by fire or other disturbance. However, complex communities, such as rainforests and coral reefs, take hundreds of years.
- Succession in plants shows variation in animals and fungal species inhabiting the place. Smaller organisms are found with pioneer species due to limited food and cover from the harsh

environment. Later with the perennial plants and a richer environment, bigger animals are also supported.



Source: *www.intothegardenstrawberries.weebly.com*

- **Example 1**: In 1965, an underwater volcano erupted near Iceland, forming a new island of hardened lava. The pioneers were bacteria and fungi, blown over from Iceland. Flies and seabird were the first to arrive. Within two years, a few small vascular plants began to grow from seeds blown over from Iceland. Two years later a few mosses appeared. The decomposition of dead organisms improved soil conditions leading to variety of plant and animal species which are still increasing.

- **Example 2**: About 10 million years ago, volcanic eruptions created Viti and Vanua Levu in the same way. A few pioneer species colonized the barren volcanic rock. Today, climax communities of rainforests and grasslands cover Fiji.

Periodicity Patterns in Plants and Animals

- Most organisms alter their activities according to the time of day and to the time of year.
- An organism's cycle of activity according to time periods are called **periodicity**.
- Periodicity divides resources between species since they are using resources at different times.
- Some common types are periodic cycles observed in organisms are:

(i) Daily Cycles

- Daily cycle is based on 24 hours.

Example 1: Birds and bats both feed upon fruits, flower nectar and insects. Both of these animal group fly. This is a relatively large niche overlap but the periodic behaviour cycles reduce competition between birds and bats. How?

- Birds are **diurnal** (**active during the day**) while bats are nocturnal (**active during the night**). Species of flowers and insects available at night differ from those available at night differ from those available during the day.

Example 2: Other organisms which show daily cycles are **crepuscular** animals which are **active near sunset** such as mosquitoes, frogs, rabbits and crabs.

Example 3: Another example of daily cycle is the **tides**. Daily there are high and low tides.

(ii) Seasonal Cycles

❖ Plants have different life cycle.

Example 1: The annual plants germinate, grow, reproduce and die all within one year. They usually begin growth in a new season before other plants. Annuals are adapted for survival in harsh, infertile environments and for wide dispersal by wind to new, unexploited habitats. Perennial plants live for more than one year. Perennials invest in support and energy storage. Normally, they flourish in areas already colonized and moderated by annual pioneer species.

Example 2: Other plants which show prominent seasonal cycles are ivi, duruka and sugarcane.

Example 3: The seasonal behaviours which are observed during winter are:
- Trees dropping their leaves;
- **Hibernation** in animals- hide and sleep through the season; and
- Some birds and mammals change from brown to white fur to camouflage in the snow.

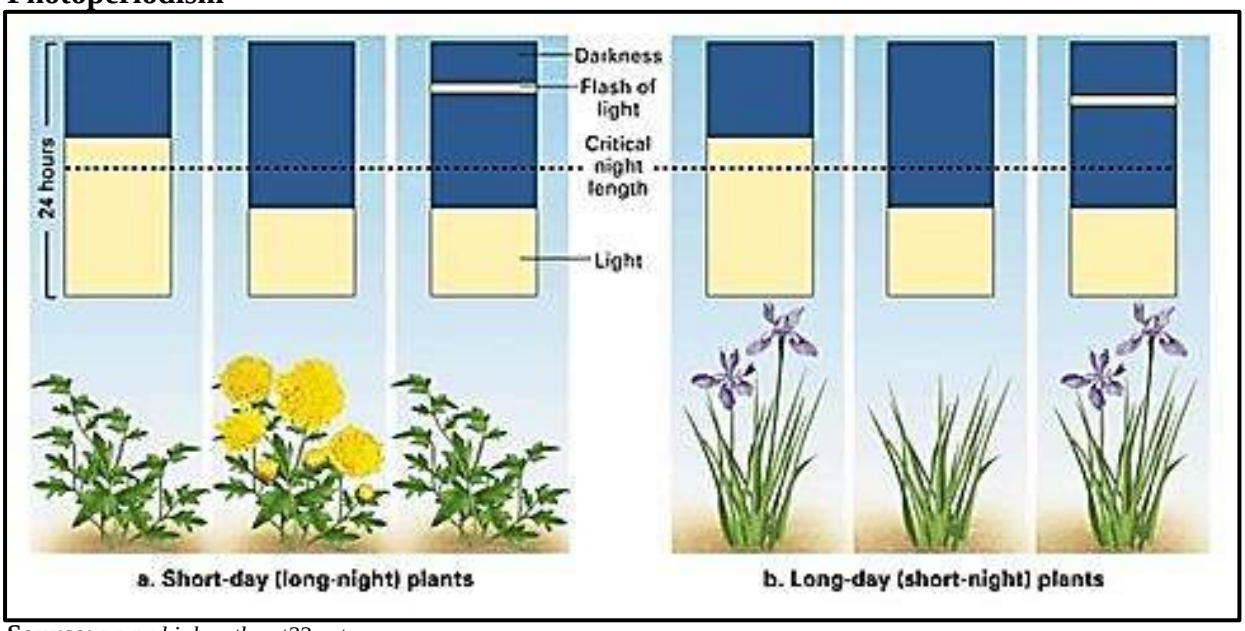
Example 4: The seasonal behaviour in response to high temperature and arid conditions:
- **Aestivation**- hides and sleeps through the season. Many land crabs spend dry seasons in an inactive state at the bottom of their burrows.

(iii) Photoperiodism

❖ Organisms can tell the time of year by the length of the day.
❖ Plants and animals time reproduction with the season that provides offspring with the best environmental conditions possible.
❖ In cold seasons, the day length is short and in hot seasons the day length is longer.
❖ In Fiji, hotter months are November and December while the colder months are around June and July. Think about the length of the day light that you get to see in these months. In June and July, at around 6 pm, it starts getting dark but at the same time in November and December, there is much more light.

Example 1: Some plants only flower when days are long and some when days are short. Some long day plants are oats, peas and wheat. The common short day plants are cotton and rice.

Photoperiodism



Source: *www.biologytb.net23.net*

Biological Principles on Community Interactions

1. **Gause's Principle of Competitive Exclusion**

- States that two species with same niche cannot co-exist in the same area for very long.
- The one better adapted to the local conditions will out-number the other.
- The 'loser' species must shift niche, migrate or die.
- **Example**: Two species of flour beetle cannot co-exist in the same jar of flour if forced to be in direct competition. However, if the environment within the flour varies a bit, for example, one part of the jar being warmer or damper than others, then the two species can specialize in these separate zones. This zonation reduces the competition between them so they can both survive.

2. **Liebig's Law of the Minimum.**

- States that out of all the resource requirements of an organism, one resource will be scarce (limited availability) than the others.
- This resource will be the limiting factor on organism's growth.
- Without more of this resource, the organism cannot take advantage of other resources even if they are plentiful.
- **Example**: Desert plants have enough carbon dioxide and sunlight for photosynthesis. But the scarce resource in deserts is water. If these plants had more water, photosynthesis would be carried out with ease, without having to invest in special adaptive structures and methods to conserve water.

Biological Principles on Community Interactions

3. Tolerance.

- Every organism can survive only within a certain range of physical factors, such as temperature, humidity and light intensity.
- The area between the minimum and maximum conditions in which the organisms can survive is called its range of tolerance.
- Within its tolerance range, an organism functions its best. Outside this ideal range, the organism becomes physically stressed and its activity level drops.
- If the conditions are way beyond the organism's tolerance range, the organism will die.
- **Example 1**: An ideal temperature range for humans to function best is between 12°C to 44°C (without clothes and shelter). If temperature falls below or rises above this range, people begin to we feel tired, lazy, frustrated and stressed.
- **Example 2**: Tolerance explains why apples trees do not grow in Fiji, why dalo do not grow in deserts and bananas do not grow in Canada.
- An organism cannot survive outside its tolerance range for any environmental factor.

SELF TEST

1. Describe your ecological niche.

2. What is the advantage of resource divisions which reduce niche overlaps of species living in the same area?

3. Several different organisms are living on the support of a sea dock. Near the high tide line, limpets and periwinkles populate the posts. Deeper in the water, beneath the low tide line, sea anemones are populating.

Limpets

Source: *www.en.wikipedia.org*

Periwinkle

Source: *www.tidings.disl.org*

Sea Anemones

Source: *www.en.wikipedia.org*

a) What kind of resource division pattern is this?
b) Name two ways the environment differs between the top and the bottom of the support posts.
c) Why don't the sea anemones also grow at the top of the support posts?
d) How are the limpets and periwinkles adapted for living above the high tide line?

4. Compare the environmental conditions in the bottom and along the sides of a drainage ditch. What kind of adaptations would plants living along the sides need as compared to those living in water at the bottom?

5. Describe two ways in which stratification reduces competition between organisms in a community.

6. Why do different species live in different strata within forests?

7. Name an organism you would expect to find living in a forest canopy and one that you would expect to find in the leaf litter on a forest floor. Describe how each of these organisms is adapted to the environment of its strata.

8. How do pioneer plants affect their environment as they take root in cleared land areas?

9. Why doesn't tree seedling colonize deserted areas?

10. Pioneer plant species are outnumbered by perennials in the areas they colonize. How do their species survive?

11. How does periodicity reduce competition can have for organisms in a community?

12. Describe advantages that periodicity can have for organisms aside from reducing competition.

13. Bats pollinate balsa tree flowers. What time does balsa flowers bloom? Explain your answer.

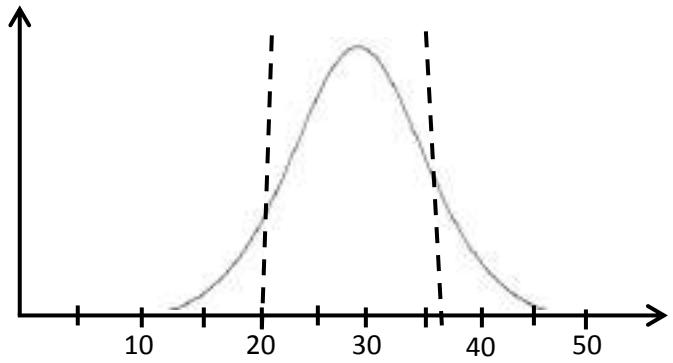
14. Describe two differences between annuals and perennials.

15. Choose the resource division pattern (zonation, stratification, succession or periodicity) which best describes each of the following situations:
a) Pawpaw tree seedling take root in the shade of tall grasses.
b) Bird nest ferns grow in the upper branches of trees.
c) Owls hunt during the night.
d) Lichens (symbiotic fungi and algae) colonize bare rock.
e) Mosses grow over the rocks along the stream and ferns grow on the upper stream banks.
f) Fungi grow in the leaf litter on a forest floor.

16. The orange fruit dove and the fruit bat in Taveuni both live on medium-sized fruits growing on forest trees. How do these two species divide their food resources to reduce competition?

17. What factors might limit the growth of a cactus plant in a desert?

18. Study the diagram of a snake's level of activity over a range of temperatures.



a) What is the snake's temperature tolerance range?
b) What is the snake's ideal temperature range? Explain how you know.
c) What happens to the level of the snake's activity as the temperature drops below 20ºC?

19. Why can't two species that occupy the same ecological niche co-exist?

20. Copy and fill in the following chart.

Type of Resource Division	Resource Divided by:	Example
Zonation	(a)	(b)
(c)	Vertical space	(d)
Succession	(e)	(f)
(g)	(h)	Hawks are diurnal, owls are nocturnal.

STRAND 3

YEAR 12

SUB-STRAND 3.1

DIVERSITY OF LIVING THINGS/ORGANISMS

SUB-STRAND 3.1: DIVERSITY OF LIVING THINGS/ORGANISMS

ACHIEVEMENT INDICATORS

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

- ✓ Research and present on the history of the different classification systems.
- ✓ Study the taxonomic rank of organisms in the three-domain and 6 kingdom system of taxonomy.
- ✓ Describe the three characteristics used to place organisms into domains.

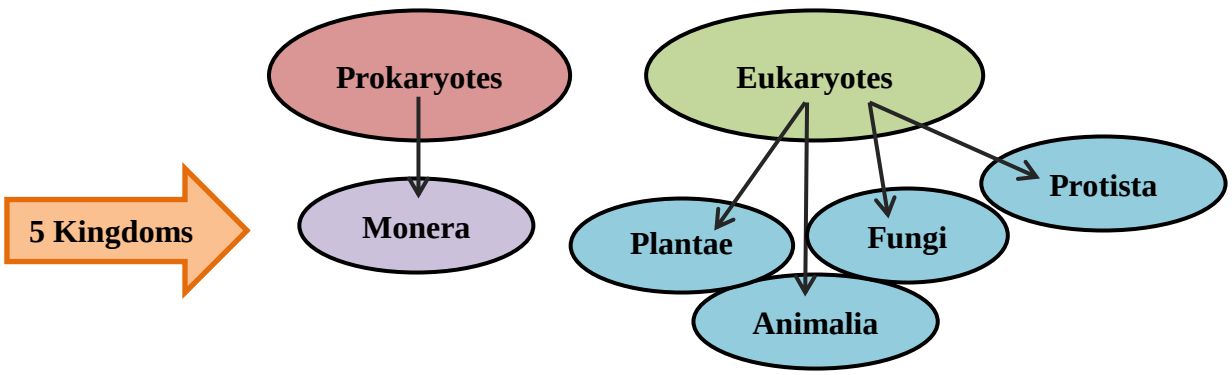
BI 12.3.1.1 TAXONOMY

In Chapter 3 of the Year 11 Course book, you learnt about Taxonomy which **categorizes** all living things into one of the Kingdoms based on their similarities. This Year we will briefly study the history of taxonomy and its applications.

Carolus Linnaeus (1707- 1778)

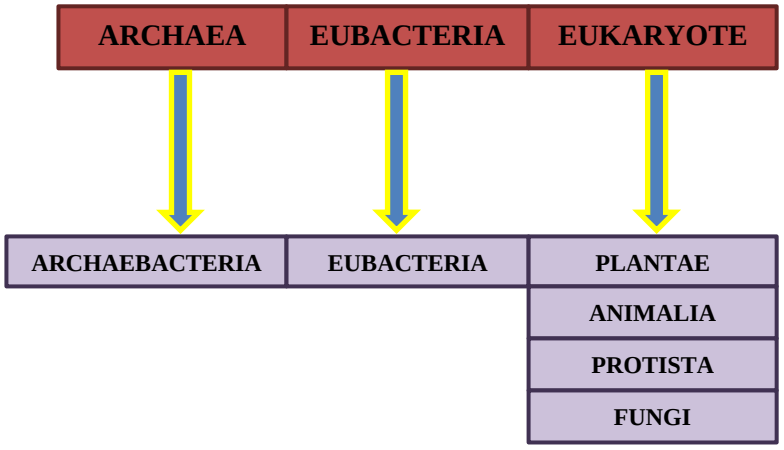
Source: *www.radiolab.org*

- Classifying organisms into some type of group is known as **taxonomy.**
- The taxonomic system was first developed by Carolus (Carl) Linneaeus.
- He identified and differentiated organisms based on physical characteristics that were common to each species.
- When Linneaeus first developed this classification system in year 1735 there were only **2 kingdoms**: **Animalia** and **Plantae**.
- Within each kingdom, he then grouped the organisms into Phylum, Class, Order, Family, Genus and Species.
- As microscopes got developed more different types of organisms were observed and it was quickly realized that there are organisms which do not fit the descriptions of either Animalia or Plantae.
- This is when Thomas Whittaker's (1969) **5 Kingdom** system got widely accepted and was used. The Animalia and Plantae remained the same; the three additional kingdoms added were: **Monera** (bacteria), **Protista**, and **Fungi**.
- While classifying, Whittaker first specified whether the organisms possessed a true nucleus (eukaryotic) or not (prokaryotic). The classification method used then was:
  - Kingdom Monera- prokaryotic and unicellular organisms.
  - Kingdom Protista- eukaryotic unicellular organisms.
  - Kingdom Plantae- eukaryotic, autotrophic organisms.
  - Kingdom Animalia- eukaryotic, heterotrophic organisms.
  - Kingdom Fungi- eukaryotic, heterotrophic organisms which unlike animals break down large organic molecules in their environment by secreting enzymes (saprophytes).



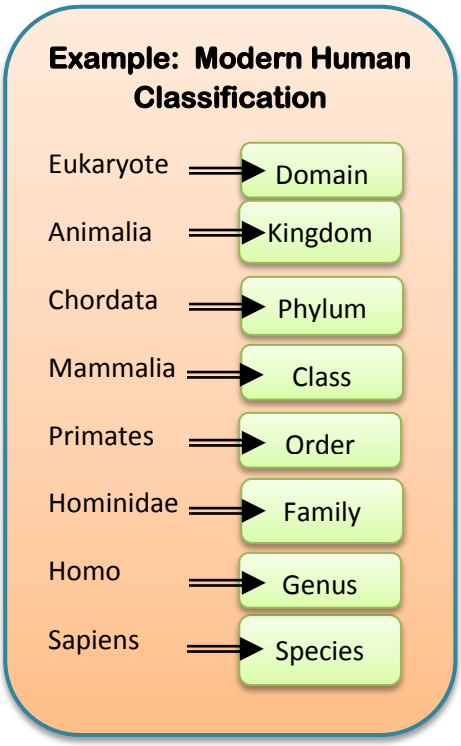
- With more advance technology such as development of DNA sequencing, electron microscopes etc; the biologists discovered that there were unicellular prokaryotic cells which differed extremely from the bacteria.
- These organisms had the ability to survive in hot springs, ice lands and other harsh environments.
- Upon these discoveries, Carl Woese proposed a reorganization of the five kingdom system into three domains. Since 1980s Woese's domain system got accepted and used.
- Woese split the previous Kingdom Monera into Domain- Eubacteria and Archaea.
- Currently, Woese's **3 Domain and 6 Kingdom** system is widely used for taxonomic classification.
- Together with that the Phylum, Class, Order, Family, Genus and Species classification continues to show how similar or different each organism is from another.
- The widely used classification system today is the **3 Domain and 6 Kingdom** classifications.

- The **three Domains** are:
  1. Archaea
  2. Eubacteria and
  3. Eukaryote



- The **six Kingdoms** are:
  1. Plantae
  2. Animalia
  3. Fungi
  4. Protists
  5. Eubacteria (Monera)
  6. Archeaebacteria

- The hierarchy grouping for each kingdom are:
  - **Phylum** (animals and bacteria)/ **Division** (plants and fungi)
  - **Class**
  - **Order**
  - **Family**
  - **Genus**
  - **Species**



Why Use Classification System?

- ❖ To study and include each organism along with its identification and habitat.
- ❖ To establish the relationship among different organisms and to understand their evolution.

Organisms are classified according to:

1. **Cell Type/ Structure**
   - ➢ Whether the cell is prokaryotic or Eukaryotic and then whether it has a cell wall or not.

2. **Nutrition**
   - ➢ Whether the organism is autotrophic heterotrophic or saprophytic.

3. **Number of cells in their body**
   - ➢ Whether the organism is single celled (unicellular) or multicellular and if multi-cellular then how the cells are organized into tissues.

SELF TEST

1. Which 2 kingdoms make up the Prokaryotic cells?

2. Which type of organisms fall in the domain Archaea?

3. What is taxonomy and who was the first person to develop the formal taxonomic system?

4. With development of modern technology, why was the 5 kingdom system quickly changed to 3-domain 6-kingdom classification system?

5. Identify the Carl's hierarchy system that is still used in conjunction with the 3-domain 6-kingdom system?

6. Which three main characteristics of the organisms are used when classifying organisms?

7. What is the difference between Eubacteria and Archeaebacteria?

STRAND 3

YEAR 12

SUB-STRAND 3.2

ENVIRONMENTAL ISSUES AND ECOSYSTEMS

SUB-STRAND 3.2: ENVIRONMENTAL ISSUES AND ECOSYSTEMS

ACHIEVEMENT INDICATORS

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

- ✓ Explain how the natural greenhouse effect is essential to sustain life on earth.
- ✓ Describe activities that lead to the enhanced greenhouse effect and its effects on the ecosystems.
- ✓ Explore the practices that help to mitigate (reduce) the effects of the enhanced Greenhouse effect.

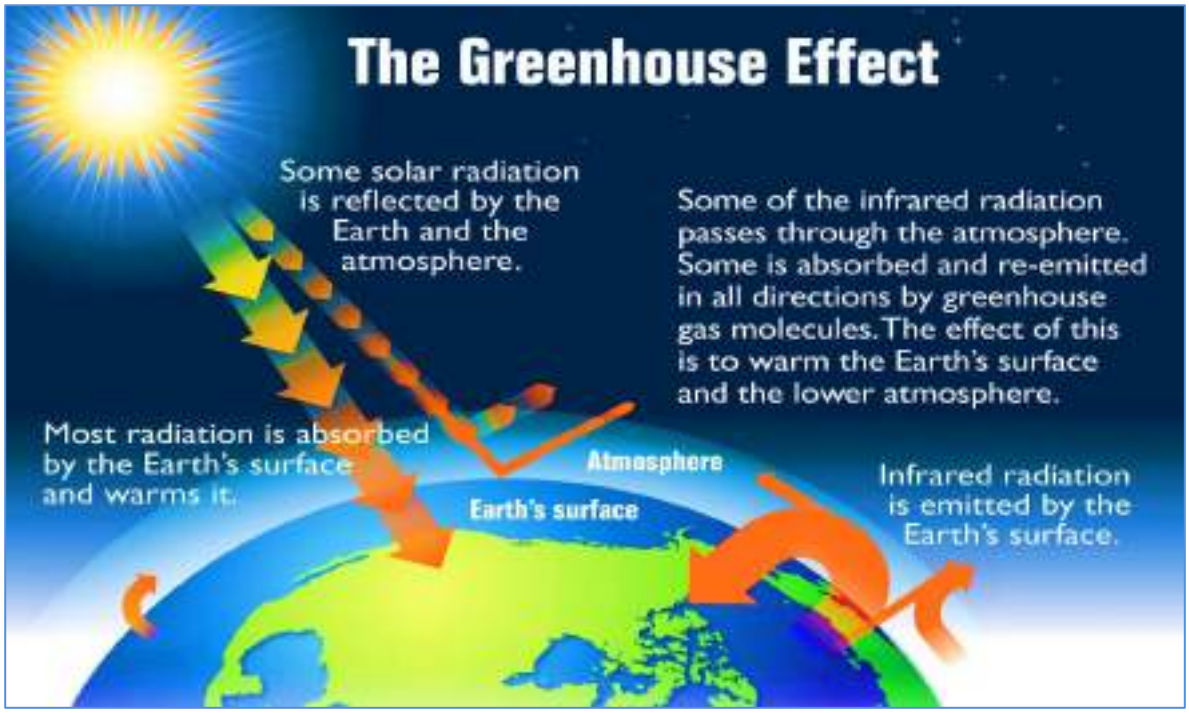
BI 12.3.2.1 Environmental Issues and Ecosystems

Source: http://www.shiawisdom.com

Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. The majority of greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere.

- Greenhouse gases act like a blanket around Earth, trapping energy in the atmosphere and causing it to warm.
- This phenomenon is called the **greenhouse effect** and is natural and necessary to support life on Earth.
- However, the build-up of greenhouse gases can change Earth's climate and result in dangerous effects to human health and welfare and to ecosystems.

The choices we make today will affect the amount of greenhouse gases we put in the atmosphere in the near future and for years to come.



Source: *http://img-0.onedio.com/img*

Greenhouse Gases

Gases that trap heat in the atmosphere are called **greenhouse gases**.

These are some of the common greenhouse gases:

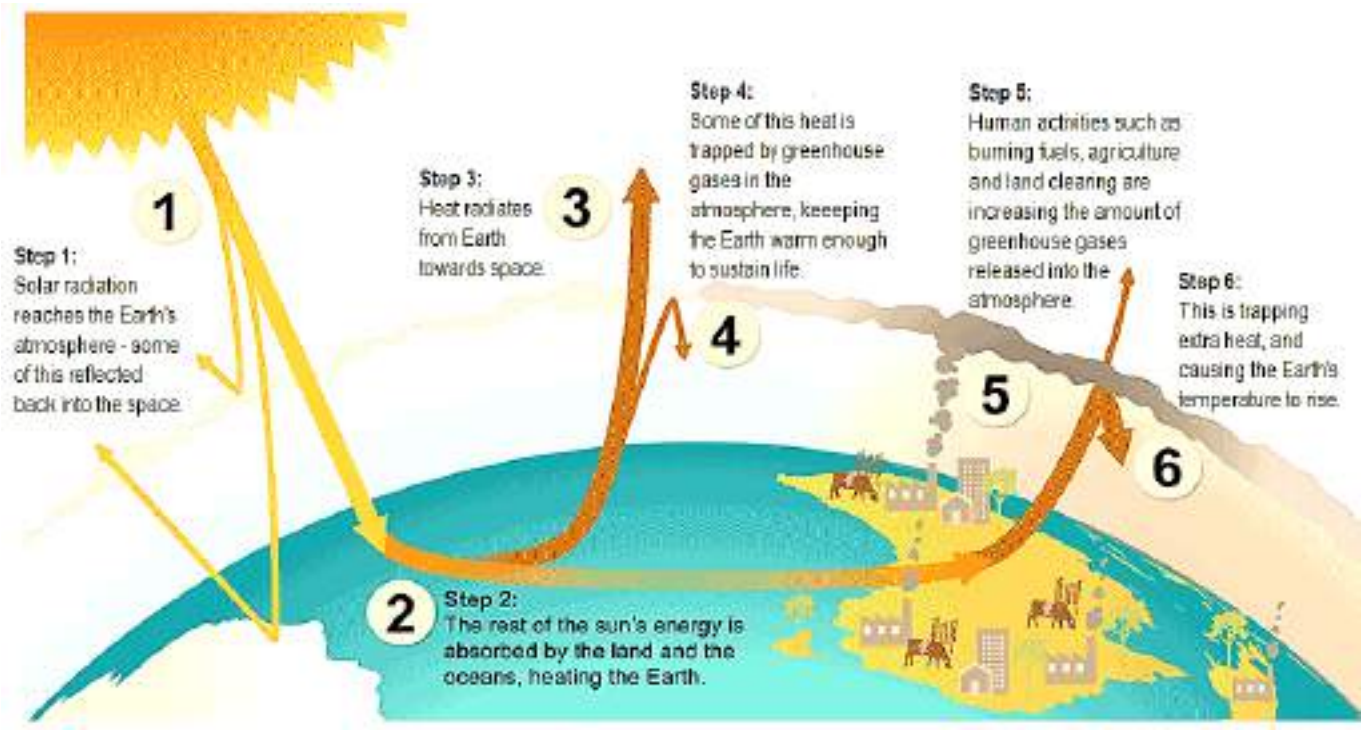
Greenhouse gases	How these gases enter the environment/ atmosphere?
Water vapour	– Water vapour is known to be Earth's most abundant greenhouse gas, but the extent of its contribution to global warming has been debated.
Carbon dioxide (CO_2)	– CO_2 is naturally present in the atmosphere. – It is also the primary greenhouse gas emitted through human activities such as combustion of fossil fuels (coal, natural gas, and oil) for energy, transportation, industrial processes, land-use etc.
Methane (CH_4)	– Emitted during production and transport of coal, natural gas, and oil. – Methane emissions also result from livestock and other agricultural practices and by decaying organic waste in solid waste landfills.
Nitrous oxide (N_2O)	– Emitted during agricultural and industrial activities – Also emitted during combustion of fossil fuels and solid waste.
Fluorinated gases (also called 'super greenhouse gases')	❖ Hydrofluorocarbons (HFC); – Man-made chemicals containing the elements carbon, hydrogen and fluorine. – are colourless, odourless and unreactive gases. – are the largest sources of fluorinated gas emissions. – fastest growing source of greenhouse gas emissions. – Sources of HFC gases include refrigerators, air-conditioners and mobile air conditioners (MAC) in vehicles (used as coolants which leak out over-time), foams (HFC creates tiny bubbles in foams) and aerosol sprays (HFC creates mist of liquid particles). ❖ Perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. ❖ Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons (CFCs), hydrochlorofluorocarbons, and halons). ❖ These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ('High GWP gases'). ❖ For a long time now human activities have been creating fluorinated gas emissions much more rapidly than the Earth can remove them, thus, increasing global levels.

Enhanced Greenhouse Effect (EGHE) / Global Warming

An increase in the concentration of greenhouse gases in the atmosphere results in more heat being retained and an overall warming of the Earth's temperature. Although they make up a small percentage of atmospheric gases, changes in the concentration of greenhouse gases have a huge effect on the balance of natural processes.

This phenomenon of warming of the earth is also known as **Global Warming**. Global warming occurs when a thick blanket of CO_2 develops in the atmosphere and traps excess heat which increases the overall temperature of the Earth.

Another major effect of EGHE is **ozone depletion**. Ozone is the layer in the atmosphere that prevents excessive UV radiation from penetrating Earth. The release of CFC gases in the atmosphere damages the ozone layer causing a hole to appear. This hole then starts allowing the penetration of UV radiation which leads to catastrophic effects like skin cancer, skin irritation, cataracts, blindness, damage to DNA and even death.



Source: *http://www.environment.gov.au/climate-change/climate-science/greenhouse-effect*

Activities that cause EGHE

1. Excessive burning of fossil fuels

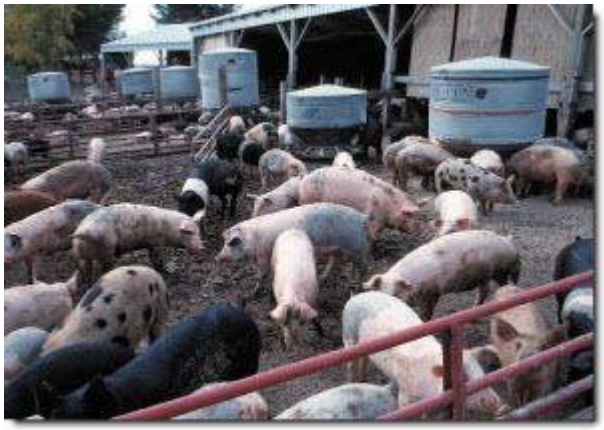
When fossil fuels are burned, they release nitrogen oxides into the atmosphere, which contribute to the formation of smog and acid rain. The most common nitrogen-related compounds emitted into the air by human activities are collectively referred to as nitrogen oxides. Ammonia is another nitrogen compound emitted to the air, primarily from agricultural activities, but also from fossil fuels.

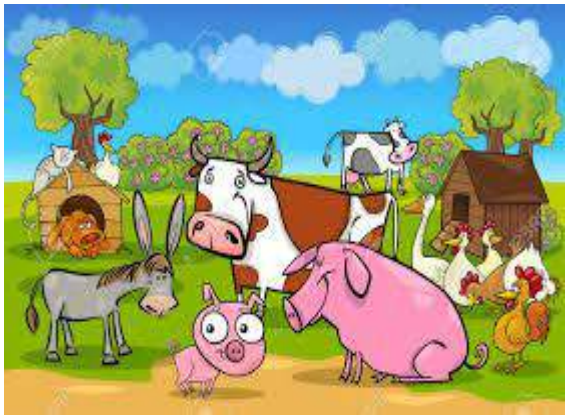
Major sources of nitrogen oxide emissions include:

- Cars and trucks
- Coal-fired power plants
- Large industrial operations
- Ships and airplanes

The presence of excess nitrogen in the atmosphere in the form of nitrogen oxides or ammonia is deposited back onto land, where it washes into nearby water bodies. These excess nutrients contribute to pollution, harmful algal blooms and oxygen-deprived aquatic zones. Excess ammonia and low pH in these areas are toxic to aquatic organisms and affect their survival.

2. Livestock Farming





Source: http://pixgood.com/cartoon-farmyard.html

Animal waste contributes excess nutrients to our waterways when manure is improperly managed.

3. Use of synthetic fertilisers

Fertilizers, yard and pet waste, and certain soaps and detergents contain nitrogen and phosphorus, and can contribute to nutrient pollution if not properly used or disposed of. The amount of hard surfaces and type of landscaping can also increase the runoff of nitrogen and phosphorus during wet weather.

Effects and Impacts of Enhanced Greenhouse Effects

1. Change in weather pattern

- The rising average global temperature is associated with widespread changes in weather patterns.
- Scientific studies indicate that extreme weather events such as heat waves and large storms are likely to become more frequent or more intense with human-induced climate change.
- As a result of the changing weather patterns, warmer water in the oceans pumps more energy into tropical cyclones and storms, making them stronger and potentially more destructive. Future hurricanes of the same intensities might cause more damage as higher sea levels exacerbate storm surges, flooding, and erosion.
- Global warming is responsible for the heavy rainfall that has led to major flooding events. This is because warmer air holds more moisture.
- Extreme precipitation is likely when a storm passes through a warmer atmosphere holding more water. In warmer months, it takes the form of torrential rainstorms.

2. Coral Bleaching

- Warmer water temperatures can result in coral bleaching.
- When water is too warm, corals will expel the algae (zooxanthellae) living in their tissues causing the coral to turn completely white. This is called **coral bleaching**.
- When a coral bleaches, it is not dead.
- Corals can survive a bleaching event, but they are under more stress and are subject to mortality.

What causes coral bleaching?

1. Change in Ocean Temperature

Increased ocean temperature caused by climate change is the leading cause of coral bleaching

2. Runoff and pollution

Storm generated precipitation can rapidly dilute ocean water and runoff can carry pollutants. These can bleach near-shore corals.

3. Over-exposure to sunlight

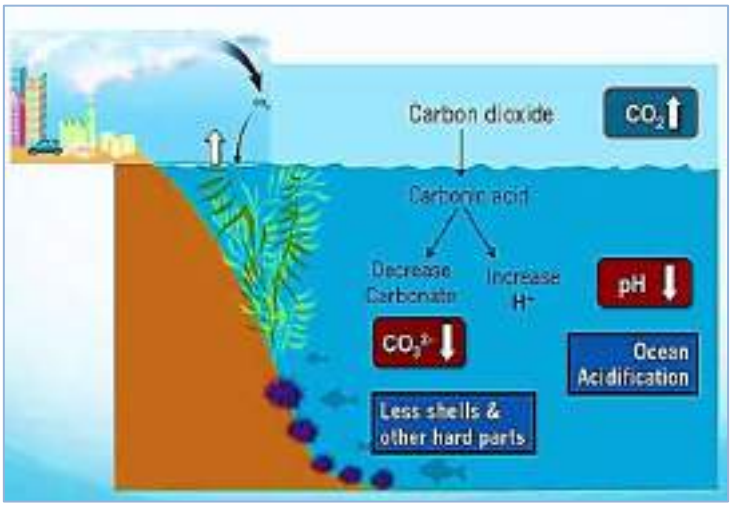
When temperatures are high, high solar irradiance contributes to bleaching in shallow-water corals.

4. Extreme low tides

Exposure to the air during extreme low tides can cause bleaching in shallows corals.

Source: http://www.usa.oceana.org

3. Ocean Acidification



Source: *http://montereybay.noaa.gov*

- As carbon dioxide (CO_2) is absorbed by the atmosphere it bonds with sea water forming carbonic acid.
- This acid then releases a bicarbonate ion and a hydrogen ion.
- The hydrogen ion bonds with free carbonate ions in the water forming another bicarbonate ion.
- This free carbonate ion would otherwise be available to marine animals for making calcium carbonate shells and skeletons.
- Dissolved CO_2 lowers the ocean's pH and leads to **acidification** which slows the atmospheric greenhouse effect and puts marine and human life at risk.
- If the acid concentrations get too high, ecosystems such as coral reefs may begin to crumble and dissolve.

4. Drought and Flooding

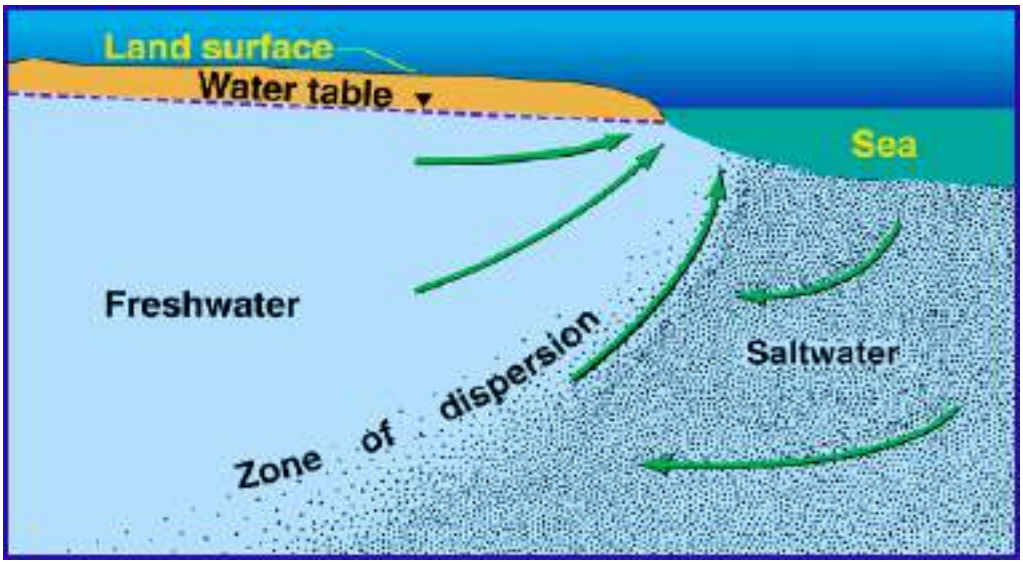
Source: *http://semillanueva.org*

- When the weather gets warmer, evaporation from both land and sea increases.
- This can cause drought in areas of the world where the increased evaporation is not compensated for by more precipitation.
- In some regions of the world this will result in crop failure and famine especially in areas where temperatures are already high.
- The extra water vapour in the atmosphere will fall again as extra rain, which can cause flooding in certain parts of the world.

5. Salt Intrusion

- Salt water intrusion occurs in coastal freshwater aquifers when the different densities of both the saltwater and freshwater allow the ocean water to intrude into the freshwater aquifer.
- These areas are usually supporting large populations where the demanding groundwater withdrawals from these aquifers are exceeding the recharge rate.
- The encroaching seawater will encounter an area known as the zone of dispersion, where the freshwater and saltwater mix and form an interface.

- This interface moves back and forth naturally because of fluctuations in the recharge rate of freshwater back into these coastal aquifers.
- Aquifers are naturally replenished by precipitation and surface waters that saturate into the ground and work their way through the soil and geologic material to the water table.



Source: *http://kanat.jsc.vsc.edu*

Impacts of Enhanced Greenhouse Gas Emissions

The release of GHGs and their increasing concentration in the atmosphere are already having an impact on the environment, human health and the economy. These impacts are expected to become more severe, unless concerted efforts to reduce emissions are undertaken.

Environmental impacts

- Overall average annual temperatures are expected to increase.
- Snow, sea ice and glacier coverage will decrease because of higher temperatures, resulting in rising sea levels and increased coastal flooding.
- Rising temperatures will also thaw permafrost in the Arctic.
- Overall precipitation levels are expected to increase across most of the country and during all seasons.
- The increase in precipitation is expected to be combined with more frequent heavy precipitation events, resulting in higher risks of flooding.
- Heat waves are likely to increase in frequency and severity, resulting in higher risks of forest fires.
- Many wildlife species will have difficulty adapting to a warmer climate and will likely be subject to greater stress from diseases and invasive species.

Health impacts

- Higher temperatures and more frequent and severe extreme weather events may increase the risk of deaths from dehydration and heat stroke, and of injuries from intense local weather changes.
- There may be a greater risk of respiratory and cardiovascular problems and certain types of cancers, as temperatures rise and exacerbate air pollution.
- The risk of water, food, vector and rodent-borne diseases may increase.

Economic impacts

- Agriculture, forestry, tourism and recreation may be affected by changing weather patterns.
- Human health impacts are expected to place additional economic stress on health and social support systems.
- Damage to infrastructure (e.g., roads and bridges) caused by extreme weather events, thawing permafrost and rising sea levels is expected to increase, impacting local populations and resource development.

Solutions to Enhanced Green House Effect

Ways in which we can reduce the impact of EGHE is by

1. **Conserving Energy**

Air pollution from energy production leads to acid rain, excess greenhouse gases, and health risks. One important step you can take to minimize air pollution is by conserving energy. This can be done by:

- Turning off lights, computers, televisions, video games and other electrical equipment when you're not using them.
- Buying equipment that uses less electricity, including lights, air conditioners, heaters, refrigerators and washing machines. Energy Star-certified products and buildings use at least 10 less energy than standard models.
- Limiting the use of air conditioning.
- Reduce, Reuse, Recycle
- Buying products with minimal packaging will help to reduce waste.
- Use Less Heat and Air Conditioning
- Drive Less and Drive Smart. Less driving means fewer emissions. Besides saving fuel, walking and biking are great forms of exercise.
- Use Less Hot Water
- Encourage Others to Conserve
- Share information about recycling and energy conservation with your friends, neighbours and co-workers, and take opportunities to encourage public officials to establish programs and policies that are good for the environment.

2. **Reforestation** – planting trees/ mangroves to replace that have been cut down. Trees absorb carbon dioxide and give off oxygen. A single tree will absorb approximately one ton of carbon dioxide during its lifetime.

3. **Renewable Energy** – using renewable energy such as wind, solar, geothermal, hydroelectric, and biomass — provides substantial benefits for our climate, our health, and our economy:

4. **Relocation** – resident of areas that are under heavy impact of climate change such as the coastal areas which are threatened by sea level rise should relocate to higher lands.

5. **Organic farming** – by use of agricultural techniques such as crop rotation composting, green manure and biological pest control instead of using chemicals that are harmful to the environment.

6. People should take heed of **awareness programs** on climate change organized by department of Environment Fiji as well as other tertiary institutes. Nowadays, several scholarships are also being offered for further study on issues related to climate change.

SELF TEST

1. Name at least three natural greenhouse gases and justify their presence in the atmosphere.
2. Differentiate between the terms ‘greenhouse effect’ and ‘enhanced greenhouse effect’.
3. What is an ozone hole?
4. Name three sources of human induced greenhouse gases.
5. Give examples of two products that contain chlorofluorocarbon (CFC).
6. List four factors that cause coral bleaching.
7. Explain the phenomenon of ‘ocean acidification’ and ‘salt intrusion’.
8. How does climate change affect the tourism industry?
9. State practices that you can observe at home to reduce the impact of EGHE.
10. How can you as a youth spread awareness in your community on climate change?

GLOSSARY

A

ABO blood type: blood type determined by proteins on red blood cell surfaces; types A and B are codominant, 0 is recessive.

Acid rain: acidic rain due to dissolved nitrogen and sulphur oxide pollutants in it.

Activation energy: the minimum amount of energy with which molecules must bump into each other to begin a reaction.

Active transport: movement of substances into or out of cells against a concentration gradient, i.e., from a region of lower concentration to a region of higher concentration; requires energy from the cell.

Adaptation: any trait that improves an organism's chances of survival and/or reproduction.

Adenine: a nitrogen-containing base found in nucleotides.

Adenosine triphosphate (ATP): a molecule which carries energy (in bonds between phosphates) from one reaction to another.

Adrenal gland: organ on each kidney that can increase metabolism by secreting adrenaline; this helps the body react in stressful situations.

Aerobic: uses oxygen.

Aerobic respiration: ATP formation from food using oxygen; releases the maximum amount of ATP from glucose.

AIDS (acquired immune deficiency syndrome): deadly disease caused by a virus that attacks the human immune system.

Algae: aquatic photosynthetic organisms that have a very simple structure, most of which are in the plant kingdom.

Alimentary canal: the gut; the passageway from mouth to anus.

Allele: form of a gene at a particular location on a chromosome.

Alveoli: tiny air sacs in the lungs where gas exchange with the blood occurs.

Amino acids: organic subunits of proteins.

Ammonia: NH3; product of deamination of amino acids.

Amylase: starch-digesting enzyme found in saliva.

Anaemia: deficiency in the number of red blood cells which usually results in tiredness.

Anaerobic respiration ATP formation from food without the use of oxygen; most of the energy in glucose is cannot be released by this reaction.

Analogous structures: structures similar in function but different in evolutionary origin.

Anaphase: stage of mitosis when sister chromatids of each chromosome separate and move to opposite sides of the cell.

Anaphase I: stage of meiosis when each chromosome separates from its homologue.

Anaphase II: stage of meiosis when sister chromatids of each chromosome separate.

Angiosperms: flowering plants; they produce seeds in flowers.

Animal: kingdom of multicellular, heterotrophic, usually motile organisms.

Annelids: animals in the phylum of segmented worms.

Annuals: plants that live for one year or less.

Antagonistic pairs: pairs of muscles that together can produce movement in opposite directions.

Anther: swollen end of a stamen in the male part of a flower that produces pollen grains.

Antibiotics: medicines that kill bacteria.

Antibodies: proteins produced by lymphocytes to help destroy antigens.

Anticodon: in a tRNA molecule, three nucleotide bases which match a mRNA codon.

Antigen: any foreign substance that causes an immune response when it enters the body.

Appendage: any moveable extension of the body, such as an arm or leg.

Arthropods: phylum of animals with exoskeletons and jointed appendages.

Arteries: thick-walled vessels that carry blood away from the heart.
Asexual reproduction: production of offspring from one parent, without the union of two gametes.
Atmosphere: the area of gases enveloping the earth.
Atom: the smallest unit of matter that still has the properties of the element.
ATP (adenosine triphosphate): a molecule which carries energy (in bonds between phosphates) from one reaction to another.
Auricles: heart chambers where blood entering the heart collects.
Autotroph: any organism which can make its own food out of inorganic ingredients.
Auxins: plant growth hormones that make cells grow longer.
Axon: long branch of a neuron that carries a neural impulse from the cell body to the synapse.

B

Bacteria: simple unicellular organisms without membrane-bound cell organelles.
Bark: collective term for all of the plant tissues outside of the xylem in a woody stem.
Base pair: a pair of nucleotide bases loosely joined in DNA or RNA, C with G and A with T.
Binary fission: the division of a bacteria cell into two.
Biennials: plants that live for two years.
Bilateral symmetry: symmetry on one plane, having two similar sides, with a definite front and back.
Biodiversity: the huge variety of different kinds of organisms on Earth.
Biosphere: areas of the earth's air, water, and soil where organisms can live.
Bipedalism: normally using two feet for standing and walking.
Birth control: devices, practices, or drugs which prevent unwanted pregnancy.
Bivalves: a class of molluscs which are enclosed in calcium carbonate shells.
Blade: large, normally flat area of a leaf that is adapted for absorbing sunlight.
Blood: tissue made up of white and red blood cells, platelets, and plasma.
Blood pressure: the pressure in the circulatory system which forces the blood forward.
Blood type: classification of an individual's blood based: on the presence of antigens on red blood cells.
Bone: a hard tissue made of protein, calcium, and phosphorus that supports the body; allows movement by providing something for muscles to pull on; makes blood cells.
Botanist: a person who studies plants.
Brain: mass of neurons that controls the rest of the nervous system.
Bronchi: two branches of the trachea which enter each lung.
Budding: a method of asexual reproduction in plants and some animals where offspring develop from an outgrowth of the parent.

C

Calvin cycle: stage of the light-independent reaction of photosynthesis; carbon-containing compounds are used to form glucose.
Cambium: group of meristematic cells that increase the width of stems or roots as they divide, thus producing secondary growth.
Camouflage: colour or behaviour adaptation that reduces an organism's chance of being seen.
Cancer: disease of uncontrolled cell division.
Canine: sharp tooth adapted for grasping and tearing food.
Capillaries: tiny, thin-walled blood vessels that allow material exchange between blood and body cells.

Carbohydrates: organic compounds that include sugars, starch and glycogen.
Carnivore: animal that eats other animals.
Carrier: female with a recessive, sex-linked gene on one of her X chromosomes.
Carrying capacity: the maximum number of individuals of a species that an area can support.
Cartilage: a firm but flexible connective tissue; it pads the ends of bones at joints.
Catalyst: any chemical which speeds up the rate of a reaction.
Cell: the structural unit of all living things.
Cell membrane: membrane that surrounds all cells and controls the passage of materials between a cell and its environment.
Cell wall: rigid outer covering of plant and fungal cells which provides support; made primarily out of a tough carbohydrate called cellulose.
Central nervous system: the brain and spinal cord.
Centriole: cell organelle which organizes the spindle fibres during cell division.
Centromere: point where duplicated
Chromosomes: are attached to one another.
Cerebellum: brain centre for reflexes, coordination, and balance.
Cerebral cortex: cerebrum covers; in humans, brain centre for "higher" brain functions such as language and thought.
Cerebrum: chief coordination centre of the brain in vertebrates.
Characteristic trait: distinguishing quality.
Chemical: bond link between atoms in a molecule.
Chlorophyll: major light-absorbing pigment in plants.
Chloroplasts: plant cell organelles filled with chlorophyll that absorb light and convert it to food energy.
Chordates: animals with a spinal cord.
Chromatography paper: a special paper used to separate plant pigments from one another in order to determine which pigments are present in a leaf.
Chromosomes: protein and DNA structures which contain an organism's genetic information.
Cilia: tiny hair-like structures that project from the surfaces of some cells; normally used in movement.
Climax community: a generally stable composition of species achieved at the end of succession in a given ecosystem.
Clones: genetically identical individuals.
Cnidarians: aquatic, radially symmetric animals.
Codominance: two alleles for one trait where neither allele dominates the other, both show in the organism's phenotype if both are in its genotype.
Codon: three nucleotide bases in an mRNA transcript which code for a particular amino acid.
Cofactor: vitamin, mineral or other chemical which an enzyme requires to function.
Cohesion: sticking together.
Commensalism: relationship where one organism's benefits and the other is not affected.
Community: the populations of all species living in a given area.
Companion cell: cell forming part of phloem that is believed to direct the flow of sap and to provide ATP to sieve cells.
Competition: interaction between organisms that need the same resource, affecting both negatively.
Competitive exclusion: the concept that populations of two species competing for a limited resource cannot coexist for long in the same habitat; one better adapted for getting the resource will survive and eventually exclude others from the habitat.
Component: part.
Concentration gradient: difference in solute concentration between two areas.
Condensation: liquid forming from a gas.
Condensation: reaction chemical reaction which, using energy, joins organic molecules together; usually forms water.

Consumers: heterotrophs; organisms which eat "ready-made," organic food.
Contractile vacuole: a cell organelle in some protists which takes up excess water and expels it from the cell by contracting.
Contrast: to compare in order to highlight differences.
Core: centre.
Cortex: the bulk of cell tissue in roots and stems which supports the plant and stores starch.
Cotyledon: seed leaves of a plant embryo.
Crepuscular: active near the time of sunset.
Cristae: the folded membrane in a mitochondria.
Crossing over: in meiosis, a section of chromosome switching places with a section from the homologue.
Cuticle: waxy outer covering on leaves and stems which reduces water loss.
Cytokinesis: the splitting of a parental cell into two daughter cells; the cytoplasm divides between the two.
Cytopharynx: a small section of the cell membrane of a *Paramecium* through which food enters food vacuoles.
Cytoplasm: all the parts of a cell between the cell membrane and the nucleus.

D

Daughter cell: cell formed by cell division.
Deamination: removal- of the amino group from amino acids.
Decomposers: organisms that get nutrients by breaking down organic compounds in wastes and dead organisms.
Dehydration: drying out.
Denaturation: a protein losing its shape and ability to function, usually due to overheating or corrosive chemicals.
Density: in population biology, the number of organisms per unit area.
Desertification: the conversion of grasslands or cropland to increasingly desert-like conditions, losing 10% of agricultural productivity or more.
Diabetes: a disease resulting from insufficient insulin production.
Dicot (dicotyledon): the most recently evolved group of angiosperms with tap roots, net leaf veins, vascular cambiums, and two cotyledon leaves in the embryo.
Diffusion: natural movement of molecules in a fluid from higher to lower concentration.
Digestion: chemical breakdown of food.
Dihybrid cross: genetic cross of two organisms homozygous for contrasting forms of two traits.
Diploid: having two sets of chromosomes, in homologous pairs.
Disaccharide: a carbohydrate of two monosaccharides bonded together.
Dispersal: spreading around.
Divergence: increasing genetic differences between two isolated groups of a population.
Diversity: many different kinds; variety diurnal active during the day.
DNA (deoxyribonucleic acid): the double-stranded nucleic acid that encodes all genetic information on how to make proteins in all organisms.
Dominant: in genetics, an allele that masks the presence of other alleles for the same trait.

E

Echinoderms: phylum of aquatic, unsegmented animals with spiny skin.
Ecology: the study of interactions between organisms and their environment.
Ecological pyramid: an illustration showing the energy content, number of organisms or biomass at each trophic level.
Ecosystem: a community of organisms and their physical environment.
Effector organs: glands and muscles.
Egestion: getting rid of indigestible food out the posterior end of the gut.

Egg: female gamete, also called an ovum.
Ejaculation: the ejection of sperm from the penis during sexual intercourse.
Electron (e-): negatively charged particle which circles around the nucleus of an atom.
Electron transport chain: a flow of electrons and/or hydrogen ions across the inner membranes of chloroplasts and mitochondria; this releases energy used to form ATP.
Elimination: egestion of undigested food from the gut.
Elongate: grow longer.
Embryo: an organism at its very early stages of development formed from a dividing zygote.
Endangered species: a species whose population has become so small that it might soon become extinct.
Endocrine system: hormone-secreting glands.
Endocytosis: a way of actively transporting large amounts of substances into a cell; the cell membrane encloses substances that are outside the of the cell, forming a vesicle which transports the materials into the cell.
Endoplasmic reticulum: stacks of folded membranes in a cell that transport proteins.
Endoskeleton: in chordates, the internal framework of cartilage and/or bone which supports the organism and aids in movement.
Endosperm: nutritious part of a seed which "feeds" the embryo.
Energy: the ability to do work.
Energy pyramid: a pyramid-shaped representation of the energy in each trophic level in an ecosystem.
Environmental variation: variation caused by external factors in an organism's surroundings, rather than by genes.
Enzyme: an organic catalyst - a protein which makes a reaction happen much more quickly.
Epidermis: the outermost layer of tissue of a multicellular plant or animal.
Epiphyte: a plant rooted on the branches of another plant instead of in the soil.
Erosion: washing away of soil.
Ethanol: the poisonous product of anaerobic respiration in plants and fungi; drinking alcohol.
Eutrophication: the process of a fresh water body dropping in oxygen content as decomposers feed on the wastes of an increased plant population.
Evaporation: liquid changing to gas.
Evolution: the gradual change of a population's genetic makeup over time.
Excretion: removal of metabolic wastes from an organism.
Exocytosis: a way of actively transporting large amount of substances out of a cell; a vesicle forms around the substance, moves to the cell membrane, and joins with it to dump the substance outside the cell.
Exoskeleton: a skeleton outside of the body, as in arthropods.
Exponential growth: pattern of population growth in which the number of individuals increases by ever larger amounts per unit of time (e.g. 2, 4, 8,16, 32, 64, etc.).
Extinction: all members of a species have died.
Extracellular fluid: watery liquid that surrounds all body cells.

F

F1: first generation of offspring in a genetic cross.
F2: second generation of offspring produced by crossing two F1 individuals.
Family tree: diagram showing the relationships between relatives over two or more generations.
Fat: a lipid with one to three fatty acid tails attached to a glycerol backbone.
Fatty acid: a compound with a long carbon backbone and a -COOH group at the end.
Fertilisation: fusion of two haploid gametes to form a diploid zygote.
Field of view: the area which can be seen under a microscope.

Flaccid: a cell that has "wilted" or become soft due to water loss.
Flagellum: the "tail" of sperm and some bacteria and protists which moves the cell forward.
Flex: bend.
Fluid mosaic model: model of cell membrane structure in which proteins are mixed with a lipid bilayer; the lipids form the basic membrane structure and keep most substances from passing through and the proteins carry out most membrane functions such as active transport, cell recognition, enzyme action and hormone reception.
Foetus: human embryo during its last six or seven months of development.
Fossil: any preserved part of an organism or imprint of an organism that lived long ago.
Fossil fuels: fuels such as coal and oil which formed from ancient plants and animals that were compressed under the earth's surface for millions of years.
Fossilisation: formation of fossils.
Fragmentation: a method of asexual reproduction where a piece of the parent breaks off and grows into a new organism.
Fruit: fertilised, mature flower ovary which protects seeds and helps to disperse them.
Fungi: the kingdom of sessile, heterotrophic organisms with cell walls.

G

Gamete: haploid cell (sperm or egg) that joins with another gamete to make a new individual in sexual reproduction.
Gametophyte: the haploid, multicellular gamete-producing phase in the life cycle of ferns, mosses and sexually-reproducing algae.
Genes: units of inheritance which each code for a protein; made of DNA.
Gene pair: in diploid cells, the two alleles on homologous chromosomes which code for the same trait.
Gene pool: total sum of all the alleles present in a population.
Genetic engineering: scientists altering the information content of DNA by changing the order -)f its bases.
Genetic recombination: a new combination of alleles in a DNA molecule due to crossing over during meiosis.
Genotype: the genes that an organism has. geotropism growth response to gravity. germination the sprouting of a seed.
Gill: a respiratory organ adapted for gas exchange with water.
Gill filaments: ridges of gills which increase surface area for gas exchange.
Gill rakers: section of the gill which traps bits of food and sweeps them towards the mouth.
Global warming: an increase in the earth's temperature due to an increased greenhouse effect.
Glucagon: a hormone secreted by the pancreas that tells the liver to convert glycogen to glucose.
Glycerol: a three-carbon molecule with three hydroxyl (-OH) groups; condenses with fatty acids to form fat or oil.
Glycogen: a large carbohydrate molecule that animals build to store glucose molecules.
Golgi body: a cell organelle that modifies and transports proteins and lipids.
Grana: structures in chloroplasts formed by stacks of folded thylakoid membrane; contain chlorophyll and other light-absorbing pigments; reaction site for forming ATP in photosynthesis.
Grazer: an animal that feeds on entire populations of organisms, often eating just part of them.
Greenhouse effect: the reflection of heat back to the earth by the layer of gases at the top of the earth's atmosphere.
Guard cells: cells that open and close plant stomata.
Gut: the tube from the mouth to the anus.
Gymnosperms: the first seed plants; they make seeds in cones.

H

Haemocoele: open blood cavity in arthropods.
Haemoglobin: the protein in red blood cells that carries oxygen.
Haploid: cell with only one chromosome of each homologous pair.
Heart: muscular pump that keeps blood circulating through an animal's body.
Heartwood: dead xylem cells filled with hardened sap at the centre of a woody stem.
Herbaceous: "soft" stemmed plants.
Herbivore: animal that eats plants.
Heredity: passage of genetic traits from parents to offspring.
Heterotrophic: need "ready-made" food; cannot make food out of inorganic materials.
Heterozygous: having two different alleles for a trait.
Hibernate: to pass the winter in a deep sleep.
HIV (human immunodeficiency virus) AIDS: causing virus which infects lymphocytes.
Homeostasis: maintenance of stable internal conditions.
Homologues: a pair of chromosomes which carry genes for the same traits.
Homologous structures: structures which have different functions but similar evolutionary ancestry.
Homozygous: having two of the same alleles for a trait.
Hormones: chemical messages which tell body tissues what to do and help to maintain a balance in body chemistry.
Host: organism in or on which another organism lives.
Hydrolysis: chemical reaction which breaks down organic molecules into smaller units, releasing energy and usually water.
Hydrostatic skeleton: body support system where internal fluid pressure protects the body shape against gravity and other forces.
Hydrotropism: plant growth response to water.

I

Immune system: vertebrate system for detecting and destroying disease-causing agents and preventing the same disease from invading again.
Incomplete dominance: one allele of a pair only partially dominates the other.
Independent assortment: genetic principle that each chromosome pair assorts into gametes independently of other homologous pairs.
Ingest: take in food into the body.
Inheritance: the transmission of genetic material from parents to offspring.
Inhibitor: a substance which can bind to an enzyme to prevent it from functioning.
Instinct: inborn skill or tendency.
Insulin: hormone made by the pancreas which tells the liver to convert glucose into glycogen.
Interphase: time interval during which a cell grows, doubles its number of organelles and duplicates its DNA.
Interspecific competition: competition between organisms of different species.
Intertidal zone: the area above the low water mark and below the high water mark on seashore; organisms living there are alternately underwater and exposed to air.
Intraspecific competition: competition between organisms of the same species.
Introduced species: species brought by humans to an area where it did not live before.
Invertebrate: any animal without a backbone; the vast majority of animals are invertebrates. ion an atom or compound with a negative or positive charge.

K

Karyotype: visual representation of all the chromosomes in a cell organised into homologous pairs.

Kidneys: in vertebrates, a pair of organs for excretion and osmoregulation which filter the blood and excrete mineral salts, nitrogenous wastes and water as needed to maintain homeostasis.
Krebs cycle: stage of aerobic respiration in which pyruvate is broken down into carbon dioxide and water, releasing ATP.

L

Lactic acid: the poisonous product of anaerobic respiration in animals.
Lamellae: thin projections from gill filaments in fish which increase surface area for gas exchange.
Lateral: sideways.
Lenticels: air channels through the bark of woody stems.
Lethal: deadly.
Lichen: a fungus and green algae living as one organism in a symbiotic relationship; populates barren habitat such as tree trunks and rock faces.
Life cycle: genetically-programmed sequence of development and reproduction events in an organism.
Light-dependent reactions (the light reactions): the first stage of photosynthesis in which sunlight is absorbed and ATP is produced.
Light-independent reactions (the dark reactions): the second stage of photosynthesis in which sugars and other compounds are made using the ATP and NADPH produced in the first stage and CO2 from the air.
Lignin: a carbohydrate in woody stem cell walls that strengthens the stem.
Limiting factor: a factor which limits population growth, such as availability of a particular resource.
Lipid: a compound mostly of carbon and hydrogen which does not dissolve in water.
Lipid bilayer: a double layer of phospholipid molecules which compose cell membranes; fatty acid tails are sandwiched between the phosphate heads.
Liver: large organ in vertebrates involved in hormone production, storing and releasing nutrients, deaminating excess amino acids, and many other functions.
Lung: internal respiratory surface adapted for gas exchange on land.
Lymph: watery fluid in the lymphatic vessels.
Lymphatic system: network of vessels and organs that help fight disease and return excess extracellular fluid to the blood.
Lymphocytes: white blood cells that fight a specific antigen during an immune response.
Lyse: to burst open.
Lysosome: cell organelle that does intracellular digestion.

M

Malpighian tubules: tube projections from an insect's gut which absorb nitrogenous wastes from the haemocoele.
Mandibles: insect mouthparts for grasping and cutting food.
Matrix space: the fluid-filled area inside mitochondria.
Medulla: part of the brain that controls basic life-sustaining reflexes such as heart rate and breathing.
Meiosis: two-stage cell division that occurs in sexual reproductive organs to produce haploid gametes.
Melanin: pigment which gives colour to skin, hair and eyes.
Meristematic tissue: plant cell tissue that divides rapidly by mitosis.
Mesophyll: spongy cell layer in the middle of a leaf.
Metabolism: all of the chemical reactions that occur in an organism, such as respiration, digestion, and photosynthesis.
Metaphase: stage of mitosis when spindle fibres form and chromosomes line up at the cell equator.

Metaphase I: stage of meiosis when homologous chromosomes pair up at the cell equator; crossing over occurs.

Metaphase II: stage of meiosis when chromosomes line up at the cell equator.

Microevolution: small changes in gene pool of a population due to natural selection or other forces.

Micrometer (µm): one millionth of a meter.

Migration: a cyclic movement of animals between two distant areas at times of seasonal change, particularly common in birds.

Mitochondrion: cell organelle that does the respiration reaction, providing energy for the cell.

Mitosis: cell division that produces two diploid daughter cells that are identical to one another and to the parent cell that produced them.

Molar: tooth adapted for crushing and grinding food.

Molecule: two or more atoms joined together.

Molluscs: phylum of soft-bodied, unsegmented, mainly aquatic animals.

Moulting: the shedding of epidermis, exoskeleton, shell, hair or feathers in a process of growth or periodic renewal.

Monocot (monocotyledon): a group of angiosperms with fibrous root systems, parallel veins in their leaves and only one cotyledon leaf in the embryo.

Monosaccharide: a single sugar unit, the simplest carbohydrate.

Monohybrid cross: genetic cross of two organisms for contrasting forms of one trait.

Motile: able to move.

Mucus: thick fluid secreted by the body.

Multicellular: made up of many cells.

Multiple alleles: three or more possible alleles for a given trait.

Mutation: random changes in DNA nucleotide base order.

Mutualism: relationship between two organisms where both organisms benefit.

N

n: number of chromosome pairs an organism has in its cell nuclei.

N: number of individuals in a population.

NAD+: a nucleic acid that carries electrons and hydrogen ions from one respiration reaction to another, forming NADH.

NADP+: a nucleic acid that carries electrons and hydrogen ions from one photosynthesis reaction to another, forming NADPH.

Natural selection: different survival and reproduction rates between organisms; usually results in an increase in the number of organisms well adapted for their lifestyles.

Nephrons: blood-filtering units in the kidneys.

Nerve: bundle of neurons and supporting cells.

Nerve impulse: electrical message that moves through neurons.

Nerve net: cnidarian nervous system without any central control.

Neuron: nerve cell.

Niche: an organism's role in an ecosystem, including its behaviour, resource needs, relationships, habitat and reproduction.

Nocturnal: active at night.

Nourish: feed, provide for.

Nucleic acid: organic molecule made up of nucleotides; DNA and RNA are nucleic acids.

Nucleolus: in the nucleus of a cell, a group of proteins and RNA which helps in making new ribosomes.

Nucleotide: an organic compound containing a sugar ring, a phosphate group and a nitrogenous base; the building unit of nucleic acids.

Nucleus: membrane-enclosed cell organelle that controls a cell's functions and contains its genetic information.

O

Omnivore: animal that eats both plants and animals.

Oral groove: indent in the cell membrane of a Paramecium which funnels food to the cytopharynx.

Organelle: membrane-bound part of a cell specialised for a particular function.

Organ: a body part made up of one or more tissues that performs particular functions.

Organic compound: a high-energy carbon-based compound.

Organism: a living thing able to maintain internal organisation and homeostasis, get and use energy, grow, respond to its environment, and reproduce.

Organ system: a group of functionally related organs.

Organic compounds: carbon-based chemicals with a lot of energy in their bonds.

Osmoregulation: maintenance of a stable internal fluid environment.

Osmosis: diffusion of water through a semi-permeable membrane.

Ovary: in female animals, the organ which makes eggs ;and female sex hormones; in plants, the female flower organ which makes seeds and becomes a fruit when fertilised.

Ovulation: release of an egg from the ovary.

Ovule: in seed plants, the structure containing the female gamete; when fertilised it becomes a seed.

Ovum: unfertilised egg; female gamete.

Oxidation: the loss of electrons from an atom or molecule; in biology, often associated with breaking down a compound such as food.

Ozone: a molecule of three oxygen atoms (0_3) which, while a pollutant near the ground, forms a protective layer at the top of the earth's atmosphere that filters out harmful ultraviolet light from the sun.

P

Palisade layer: cell layer just below a leaf's surface that does most of the photosynthesizing.

Pancreas: vertebrate animal organ that makes digestive enzymes and hormones.

Paralysis: the loss of movement or sensation in one or more body parts.

Parasite: organism that gets food by living in or on another organism, which is called its host.

Passive transport: movement of substances in or out of cells down the concentration gradient, i.e., from higher to lower concentration; requires no energy (e.g. diffusion and osmosis).

Pathogen: disease-causing organism.

Penis: male reproductive organ that serves to deposit sperm into a female of the species for sexual reproduction.

Pepsin: enzyme produced by the stomach that digests proteins.

Peptide: a short chain of amino acids joined by peptide bonds.

Peptide bond: a bond between amino acids formed by a condensation reaction.

Perennials: plants that live for more than two years.

Peripheral nervous system: the nerves throughout the body controlled by the brain Ind spinal cord.

Peristalsis: waves of muscle contraction to produce movement, such as pushing food through the gut.

Petrify: to change into stone; to harden.

pH: the acidity or alkalinity of a substance m a scale of 0-14.

Phagocytes: white blood cells which ‘clean up’ the blood by surrounding and digesting my foreign or damaged material.

Pharynx: part of the digestive tract between

Phenotype: observable characteristics of an organism that are an expression of its genotype.

Phloem: plant vascular tissue that carries dissolved sugars from the leaves to other parts of the plant.

Phospholipid: the main component of cell membranes; a molecule with a phosphate head and two fatty acid tails.

Photolysis: in the light-dependent stage of photosynthesis, the splitting of a water molecule into oxygen, hydrogen and electrons.

Photosynthesis: the conversion of light energy to food energy by plants: (CO_2 + H_2O + light energy+ $C_6H_{12}0_6$ + 0_2).

Phototropism: growth response of a plant to light.

Phytoplankton: community of tiny aquatic photosynthetic organisms.

Pigment: coloured chemical.

Pioneer species: various species with short life cycles adapted to growing under harsh environmental conditions; they set the stage for their replacement by other plant species by improving the conditions of the habitat.

Pituitary gland: the "master gland" which secretes hormones that affect most of the other glands in the endocrine system.

Plant: kingdom of autotrophic, normally multicellular organisms having cell walls.

Pollen: male gamete of flowering plants; contain sperm.

Pollination: the transfer of pollen from an anther to a stigma.

Pollutant: any substance an ecosystem has not previously experienced in its development, whether in kind or in amount.

Polyp: completely sessile stage in the life of a cnidarian.

Polypeptide: chain of amino acids linked by peptide bonds formed by condensation reactions.

Population: individuals of the same species living in an area all at the same time.

Predation: a predator hunting and killing

Prey: animal which is hunted by a predator.

Primary growth: growth in plant length due to division of primary meristems at the tips of roots or stems.

Primates: order of mammals most of whom have opposable thumbs and high intelligence, including monkeys, apes and humans.

Probability: chance of an event occurring.

Producer: autotrophic organism.

Prophase: first stage in mitosis when duplicated chromosomes condense.

Prophase I: the first stage in meiosis when the chromosomes condense and begin to pair with their homologues.

Prophase II: a brief stage at the start of meiosis II before the sister chromatids separate.

Protein: molecule composed of one or more polypeptide chains.

Protein synthesis: the building of proteins on the endoplasmic reticulum according to instructions from DNA.

Protist: kingdom of unicellular organisms with cell organelles.

Punnett square method: diagram used to make it easier to predict possible genotypes in their expected ratios from a genetic cross.

R

Radial symmetry: symmetry on more than one plane.

Range: area where a population lives.

Receptor: in nervous systems, a sensory cell which can be activated by a specific stimulus.

Recessive: an allele that does not show in the phenotype if the dominant allele is also in the genotype.

Reflex: very simple, involuntary and fast neural response involving only a sensory neuron, interneuron and a motor neuron.

Resource divisions: community patterns of sharing the same resource in different ways, areas or times.

Ribosomes: cell organelles that make proteins.

RNA (ribonucleic acid): nucleic acids involved in transcribing and translating DNA into actual proteins.

Root hairs: small "hairs" that stick out of root epidermal cells, thus increasing surface area for absorption.

Root pressure: osmotic pressure of water moving into a root from the soil.

S

Sanitary: free of pathogens.

Sap: sugary fluid in plant vascular tissue.

Secondary growth: growth in plant width produced by division of meristematic cells in the cambiums of dicot plants.

Secretion: release of materials produced by a cell.

Seed: fertilised ovule made up a plant embryo, endosperm and seed coat.

Segmentation: a series of separate body units in animals.

Semi-permeable: some things can pass through and others cannot.

Sessile: moves very little or not at all.

Sex chromosomes: the only chromosome pair that is different in males and females; contain the genes that cause sex differences.

Sex linked traits: traits controlled by genes located on the sex chromosomes, normally the X chromosome.

Sexual reproduction: production of genetically unique offspring by the joining of two haploid gametes.

Sieve cells: cells making up the part of phloem which carries sap.

Sister chromatids: two identical copies making up a duplicated chromosome.

Solute: any substance dissolved in water or other solvent.

Somatic cells: body cells; cells that make up most of an organism and divide only by mitosis.

Speciation: divergence resulting in a new species.

Species: organisms all of the same kind which can interbreed and produce fertile offspring.

Specimen: sample of something to be examined.

Sphincter: ring of muscle.

Spindle fibres: cell structure which forms during cell division to pull chromosomes apart.

Spongy mesophyll: leaf layer with lots of air spaces which allow faster gas exchange with the environment.

Spores: haploid reproductive cells of simple plants such as mosses and ferns.

Sporophyte: the diploid spore or seed-producing stage of plant life cycle.

Stamen: male reproductive organ in a flower, made up of filament and anther.

Starch: a large carbohydrate molecule that plants use to store glucose.

Sterile: unable to have offspring.

Stigma: sticky structure where pollen lands at the top of the female organs in a flower.

Stimulus: any external change that can organism can sense.

Stomata: small holes on the underside of a leaf that allow gas exchange.

Stroma: the liquid-filled area in chloroplast; site of dark reaction.

Style: part of the pistil which connects the stigma to the ovary.

Substrate: molecule(s) upon which an enzyme acts.

Succession: the orderly changes in species composition from the first colonising pioneer species to a climax community.

Surface-area-to-volume ratio: the proportion of an objects surface area to its volume; in cells, a physical limit on increased size; as a cell grows, its surface area does not increase as much as volume, decreasing its SA: V ratio.

Survivorship curve: graph which reflects the age-specific death patterns for a population.

Symbiosis: mutualistic relationship between organisms upon which both organisms are dependent for survival.

T

Tap root system: root system of one main root with many smaller side branches; found in dicots.

Telophase: final stage of mitosis when cytokinesis occurs and chromosomes de-condense.

Telophase I: the last stage of meiosis I when the parent cell finally splits into two haploid cells with chromosomes still duplicated.

Telophase II: the last stage of meiosis II when cytokinesis creates four gametes from the two cells resulting from telophase I.

Terrestrial: living on land.

Thylakoid membrane: the membrane inside a chloroplast; site of the light reactions.

Thyroid gland: gland in the throat that controls metabolic rate with the hormone thyroxin.

Tissue: a group of similar cells that are specialised for a particular function.

Toxic: poisonous.

Trachea: in insects and spiders, an air-conducting tube the branches through the body; in land vertebrates, the windpipe between the throat and bronchi.

Trait: characteristic.

Transcription: in protein synthesis, the assembly of a RNA strand on a DNA strand; the resulting order of nucleotide bases on the mRNA transcript represents the base order of the DNA.

Translation: in protein synthesis, tRNA brings amino acids to the mRNA transcript, creating a protein according the instructions of the original DNA strand.

Transpiration: evaporation of water from a plant.

Transpirational pull: water evaporation from the leaves sucking water up from the roots of a plant.

Trophic level: stage along a feeding pathway; an organism's distance from the sun as an energy source along a food chain.

Tropism: plant growth response to environmental stimuli.

True-breeding: homozygous for every trait.

Turgid: full of water.

Turgor pressure: internal pressure in a plant cell caused by the osmosis of water into the cell.

U

Ultraviolet light: UV light; these invisible rays from the sun can cause cancer, kill microorganisms and reduce immune function.

Unicellular: made up of only one cell.

Urea: slightly toxic nitrogenous waste formed from ammonia by the liver.

Uric acid: insoluble nitrogenous waste produced by most terrestrial egg-laying animals.

Urine: solution of nitrogenous wastes, water and salts for excretion.

Uterus: organ in female mammals inside which an embryo develops.

V

Vacuole: a storage organelle in cells; in plant cells a very large vacuole stores food and pushes other organelles closer to the membrane.

Vagina: female vertebrate's entry for sperm deposit by a male's penis and, in mammals, the birth canal.

Variation: differences.

Vascular: relating to transport tubes.

Vascular plants: the most modern group of plants, distinguished by their vessels for water and food transport.

Veins: blood vessels in animals that carry blood towards the heart.

Ventricle: chamber of the heart that contract to pump the blood out through the arteries.

Vertebrates: animals with a backbone.

Vesicle: in a cell, a small membrane-bound sac which stores or transports materials.

Villi: finger-like projections of the small intestine wall which increase the surface area for nutrient absorption.

Virtually: almost.
Virus: very tiny structure made up only of DNA and a protein coat; most are pathogenic; they are not truly alive because they need a host cell to reproduce.
Vestigial structure: structure inherited from evolutionary ancestors which no longer has any function.
Vitamins: any organic compound needed in small quantities to work as cofactors for enzymes.
Vulnerable: easily hurt.

W

Wilting: drooping of plant stems and leaves due to water loss; the cells are flaccid.

X

X chromosome: a sex chromosome; females have two, males have only one.
Xylem: plant vascular tissue that transports water from roots to other plant parts.

Y

Y chromosome: the male sex chromosome; males have one X and one Y chromosome. yolk sac a "bag" of nutrients for sustaining a developing embryo in an egg.

Z

Zygote: fertilised egg; diploid cell that results when a sperm fertilises an egg.

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