Chapter 7 - The Basis of Life

Microscopes
Cell Theory
Cell Structure

Compound Light Microscopes

Light rays passed through a specimen are brought into focus by a set of lenses and viewed by the eye.

Maximum Magnification is about 1000x

Can be used to view living or dead specimens

Resolution

Resolving Power (Resolution): the minimum detectable distance between two points

Light microscopes have a resolution of 0.0002mm (or 0.2um)

(so objects closer than 0.0002mm together are seen as one object)

compared to the human eye which has resolution of 0.2mm!
Units of Measurement

When you use a microscope you have to calculate the

- Magnification
- Field of View Diameter
- Scale

Objects under a microscope are very small, so we use the units micrometers ($\mu$m)

$1000\ \mu$m = 1 mm

To convert from mm to $\mu$m you multiply the value (in mm) by 1000

Measurement Practice

| 0.018 mm | = ______ $\mu$m | 250 $\mu$m | = ______ mm |
|------------------|------------------|------------------|
| 240000 $\mu$m | = ______ mm | 32000 $\mu$m | = ______ mm |
| 364 mm | = ______ $\mu$m | 0.567 mm | = ______ $\mu$m |
| 4.5 mm | = ______ $\mu$m | 0.897 mm | = ______ $\mu$m |
| 79 mm | = ______ $\mu$m | 27.5 mm | = ______ $\mu$m |

Magnification

To determine the magnification of a light microscope you multiply the magnification of the objective lens you are using by the magnification of the eyepiece (ocular lens)

$Total_{Mag} = Objective_{Mag} \times Ocular_{Mag}$

Example: Your using the 40x objective and 10x eyepiece, what is the magnification of the image?

What would be the total magnification using the 10x and 20x objectives be?

Field of View (FOV) Diameter

Field of view (FOV) diameter is the measure of the width of the circular area seen through the ocular lens.

To measure: place a ruler on the stage, focus and count the number of mm across the view. (convert to $\mu$m if necessary)

By comparing the image you see to the FOV diameter you can estimate the actual size of the specimen.
Field of View (FOV) Diameter

Example:

1. If each division is 1mm what is the FOV diameter in mm and μm?

Field of View (FOV) Diameter

Example:

2. The FOV diameter of the low power of your microscope is 2000 μm. If 4 lily plant cells fit across the FOV, how long is each lily cell?

We can use this formula to figure it out:

Size of Object (SOO) = FOV diameter
Fit Number

Relating Magnification and FOV

An inverse relationship exists between Magnification and FOV. As magnification increases, the FOV diameter decreases. If you measure the FOV diameter under one magnification, you can calculate it under the others using the following formula:

\[ \text{Mag}_1 \times \text{FOV}_1 = \text{Mag}_2 \times \text{FOV}_2 \]
Relating Magnification and FOV

Examples:

1. A microscope has a medium power magnification of 100x and field of view of 1.75mm. What is the field of view diameter of the high power magnification of 400x? (in mm and $\mu$m)

2. A student counts 6 cells across the diameter of the field of view of a microscope and 8 rows of cells down. The magnification is 50x and the diameter of field of view is 2400 $\mu$m. What is the length and width of each cell (in $\mu$m)?

   If the magnification increased to 200x, how many cells would be seen across and down the field of view?

Scale

The scale of a biological drawing is used to approximate the actual size of the specimen.

\[
\text{Scale} = \frac{\text{Size of Drawing (SOD)}}{\text{Size of Object (SOO)}}
\]

Remember SOO = FOV

FIT

The size of drawing is the measured width of your finished drawing. Convert both SOD and SOO to same units so they cancel out. Scale is a ratio.

(ex. 47.6 would be 48:1)

Making Biological Drawings

All biological drawings have the same strict rules to follow:

1. Pencil on unlined, blank white paper
2. Draw only ONE cell/image and only what you can see
   *pick a single cell to draw that is clear and easy to see*
3. The drawing should take up about half the space of the paper
4. Use single lines to outline and fill in details with dots
   *Do not shade in or colour the drawing!!*
5. Label structures using straight horizontal lines that do not cross and all lowercase letters
6. Measure the length of your finished drawing in milimeters

Making Biological Drawings

7. Print the Title above the drawing - Should state the object of the drawing and the magnification
   
   Ex. Onion Root Tip 200x

8. In the LOWER RIGHT CORNER include:
   *Your name*
   *Size of the Object (actual)*
   *Scale of the Drawing (ex. 1cm = 0.125mm)*

9. On the BACK of the paper include calculations for:
   *Magnification*
   *FOV diameter*
   *Fit number*
   *Calculated size of object*
Early Theories of Life

Aristotle’s spontaneous generation theory stated that life can be created from non-living matter. (also called Abiogenesis)

This was the ruling theory for thousands of years.

In 1668, Francesco Redi performed an experiment to disprove spontaneous generation.

Redi’s Evidence: Flies must be present to lay eggs on a non-living substance for new flies to be produced.

Supporters of Spontaneous Generation argued that air carried an ‘active principle’ which in the sealed jar was absent.

In 1800’s microorganisms were discovered.

In 1858, Rudolph Virchow first proposed the theory of Biogenesis or ‘life from life’.

In the mid 1800s Louis Pasteur performed many experiments on using microorganisms. He developed pasteurization as a way of sterilizing liquids and many vaccines.

He also disproved spontaneous generation theory.
The cell is the single fundamental unit of life.

Living organisms can be made up of one cell "Unicellular" or many cells "Multicellular".

In multicellular organisms cells specialize to carry out certain functions

   Ex. Muscle cells

Development of the microscope and advanced imaging technologies has allowed us to gain information and knowledge of cells and how they function.

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In 1665, Robert Hooke released a publication where he described cork (plant cells) under the microscope as tiny boxes. He called them 'cells', which is the origin of the term we still use.

In 1674, Antoni van Leeuwenhoek developed microscopes with greater magnification to view smaller organisms, such as bacteria.

He is called the "Father of Microbiology"

The Cell Theory was proposed in 1839 by Schleidan and Schwann and later on Virchow's evidence was added.

1. All organisms are composed of one or more cells
2. The cell is the smallest functional unit of life
3. All cells are produced from pre-existing cells
Development of the Cell Theory

Before van Leeuwenhoek's microscope objects smaller than 1mm could not be seen!

Current electron microscopes can produce images of objects magnified up to 300000x their actual size!

Advanced Imaging Technologies

Phase Contrast Microscopes

A light microscope that uses special lenses to view living specimens when they are growing and dividing.

They amplify density variations within the specimen to improve contrast of unstained samples.

Advanced Imaging Technologies

Confocal Laser Scanning Microscopes

A light microscope used to produce high resolution 3D images.

Images are taken at many various depths of the specimen using a laser, they are reconstructed by a computer to produce a 3D image.

Litchmann from Harvard used different coloured fluorescent labels to identify each individual neuron cell in mouse brain tissues.

This method is called “Brainbow”
Advanced Imaging Technologies

Electron Microscopes

First developed in the 1930s

A beam of energized electrons are aimed at a specimen to produce a detailed image of its surface

Very high magnification (1,000,000x) and resolution (200nm)

Used to view plant and animal cells, bacteria, macromolecules and viruses

Two common types used:
- Transmission Electron Microscopy (TEM)
- Scanning Electron Microscopy (SEM)

Transmission Electron Microscope (TEM)

Electrons are focused by a set of magnets producing a flat, 2D image.

The specimen is fixed(killed) and sliced into 100nm thick sections, placed on a metal grid, stained and then viewed.

Used to study internal structures

Scanning Electron Microscope (SEM)

Electrons are fired at the surface of specimen producing a 3D image.

The specimen is coated in a thin layer of metal which the electrons bounce off of and then viewed.

Used to study external structures and shapes

SEM vs TEM

Pollen grain under SEM and TEM

Scanning Electron Microscope (SEM) vs Transmission Electron Microscope (TEM)
Advanced Imaging Technologies

Comparing Imaging Technologies

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Maximum Magnification</td>
<td>1000x</td>
<td>1,000,000x</td>
<td>100,000x</td>
</tr>
<tr>
<td>Maximum Resolution</td>
<td>200nm</td>
<td>0.2nm</td>
<td>2nm</td>
</tr>
<tr>
<td>Image produced by</td>
<td>Light passes through specimen</td>
<td>Electrons pass through specimen</td>
<td>Electrons bounce off the specimen</td>
</tr>
<tr>
<td>Focusing done by</td>
<td>Glass lenses</td>
<td>Electromagnets</td>
<td>Electromagnets</td>
</tr>
<tr>
<td>Image produced on</td>
<td>The Eye or a monitor</td>
<td>Monitor</td>
<td>Monitor</td>
</tr>
<tr>
<td>Quality of Image</td>
<td>Colour, 2D, internal structure</td>
<td>Black and White, 2D, internal structures</td>
<td>Black and White, 3D, surface details</td>
</tr>
<tr>
<td>Advantages</td>
<td>Living material can be viewed, cheap and readily available</td>
<td>High quality image and magnification, details of internal structures</td>
<td>High quality image and magnification, easy to interpret</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Low magnification, 2D image</td>
<td>Dead specimens, difficult to interpret</td>
<td>Dead specimens, only details of external structures</td>
</tr>
</tbody>
</table>

Advanced Imaging Technologies

Scanning Tunnelling Microscope (STM)

Developed in 1980s

Non-optical microscope with greater magnification than electron microscopy. Used to image molecules such as DNA and proteins.

Allows scientists to predict the position of individual atoms and molecules to produce a 3D image.

A metal probe is placed near the specimen, electrons flow between the probes and specimen surface and a computer interprets the information to produce an image.
Advanced Imaging Technologies

Scanning Tunnelling Microscope (STM)

Iron atoms on a Copper surface

Strand of DNA

What is Cancer?

Cancer is caused by damage to the DNA inside the cells nucleus, leading to uncontrolled, rapid cell growth.

Mutations are changes in the sequence of nitrogen bases in DNA molecules (There are 4 bases: A, C, G and T)

DNA contains the code for making all molecules in the cell, so a change in the code results in different molecules being made, often dysfunctional.

The more mutations the DNA undergoes the more risk of a cancerous mutation occurring.

As DNA is copied for a new cell division mistakes can occur, causing mutations.

FYI - HeLa Cells

In 1951, cells were isolated from a cervical tumour in Henrietta Lacks at John Hopkins medical centre in Baltimore, Md.
• These were the first cells successfully grown in culture in a laboratory.
• On October 4, 1951 Henrietta passed away. Her body had become overrun by tumours in her lungs, diaphragm, bladder, kidneys and intestines to the point that she appeared to be six months pregnant.
• The immortal HeLa cells resulting from this tumour have shaped scientific research, led to the polio vaccine, HIV and other antibody related diagnostic tests, furthered understanding and treatment of cancer, and were instrumental in completing the Human Genome Project.

Divide and Conquer: HeLa cell splitting into two new cells. Paul D. Andrews
**FYI - Stem Cell Characteristics**

Stem Cells are self-renewing, undifferentiated cells with no specific function. They can be stimulated by chemicals called growth factors, to differentiate and form specialized cells.

Sources of stem cells include:
1. Developing embryos
2. Umbilical cords
3. Some adult tissues
   - Ex. bone marrow

All stem cells must have two characteristics:
1. Have the capacity to divide and renew themselves for long periods of time
2. Be capable of being stimulated to generate multiple, differentiated cell types

**Types of Stem Cells:**

- **Totipotent** stem cells have total potential to direct the development of an entirely new organism
  - Are present in developing embryos between Day 1 and Day 5 before any cell specialization begins
  - The only research involving TSC’s would be related to reproductive medicine

- **Pluripotent** stem cells are capable of differentiating into any of the ~220 types of body cells
  - Harvested from the inner cell mass of embryos at the blastocyst stage of development (Day 6 – 10).
  - After Day 10, cells undergo further differentiation and are no longer capable of producing all types of body cells

- **Multipotent** stem cells have limited potential as they have differentiated beyond the pluripotent stage. Multipotent cells are capable of differentiating into many types of cells but lack the potential to form all 220 types of body cells.
  - Example: Bone marrow cells can form platelets (clotting cells), red blood cells, and many different types of white blood cells but cannot form bone or muscle cells

**FYI - Stem Cell Characteristics**

Animal stem cells—self-perpetuating, undifferentiated cells that can give rise to specialized cells of various types—can be isolated from early embryos or adult tissues and grown in culture. Researchers are seeking to discover the growth conditions that direct stem cells to differentiate into particular cell types.

**What stimulates Stem Cells to Develop?**

All cells develop under the influence of signaling molecules called **growth factors**

- These growth factors are produced by cells and released into the extracellular environment where they can influence the development and specialization of other neighborhood cells by activating different DNA programs
FYI - Stem Cell Characteristics

Potential uses of Stem Cells

1. Cell-based therapies:
   - Transplanting or grafting tissues to help with a shortage of organ donors
     * Eg. Parkinsons, Alzheimers, heart disease, cancer, spinal cord injuries, etc.
   - Multipotent stem cells currently used in medical therapies such as stem cell transplants into bone marrow or heart muscle

2. Testing new pharmaceutical drugs:
   - Testing medications for safety on differentiated cells from pluripotent cells lines
     * Eg. Cancer fighting drugs are tested on cancer cell lines

3. Understanding cell division and development:
   - Discovering the process that turns genes on and off to control cell division
     * Eg. Attempting to control the rapid growth of white blood cells in leukemia patients
   - Learning more about cancer and birth defects

4. Uncovering the mysteries of various diseases:
   - Genetic diseases can be better understood by studying cells with specific mutations that cause disease
     * Eg. Cell lines have been made from embryos carrying the mutation that causes cystic fibrosis and research can be done on these cell lines

Biological Kingdoms

Used to categorize biological life forms based on their similarities

Prokaryotes
- Eubacteria
- Archaebacteria

Eukaryotes
- Protista
  - Fungi
  - Plants
  - Animals

Prokaryote and Eukaryote cells

Prokaryote and Eukaryote are the two main different types of cells

They have some similarities but some important differences.

Prokaryotic cells do not have organelles (internal membrane-bound structures). In general they are more primitive and simpler than the more complex eukaryotic cell. Many of these organisms are unicellular.
Prokaryotic Cells

Prokaryotic means “before the nucleus”
• Believed to be ancestors of life on earth ~3.5 bya
• Include the true bacteria (eubacteria) and ancient bacteria (archaebacteria)

Characteristics of Prokaryotic organisms:
- No membrane-bound organelles
- No nucleus means the DNA is free floating
- DNA tends to group together in an area called the nucleoid
- Have small ribosomes to direct protein synthesis
- Cell metabolism is either aerobic (use O2) or anaerobic (do not use O2)
- No cytoskeleton
- Majority are unicellular (single celled)
- Majority reproduce asexually by binary fission (means splitting in two)
- Cells are extremely small (1 – 10 μm)

Eukaryotic Cells

Eukaryotic means “true nucleus”
• Believed to have emerged ~1.5 bya through endosymbiosis, the theory that free-living prokaryotic cells were engulfed by larger cells to form more complex cells
• Include protists, fungi, plants, animals

Characteristics of Eukaryotic Cells:
- Have complex membrane-bound organelles
- Has a nucleus (nuclear envelope is a membrane that encloses DNA)
- Cell metabolism is primarily aerobic (requiring O2)
- Some are unicellular (eg. Paramecium) but most form multicellular organisms
- Can reproduce both sexually and/or asexually
- Cells are larger in size (10 – 100 μm)

FYI - Endosymbiotic Theory

In the 1980s, Lynn Margulis proposed the theory of endosymbiosis to explain the origin of mitochondria and chloroplasts from permanent resident prokaryotes. According to this idea, a larger prokaryote (or perhaps early eukaryote) engulfed or a smaller prokaryote between 1.5 billion and 700 million years ago.

Steps in this sequence are illustrated below:
Instead of digesting the smaller organism, the large one and the smaller one entered into a type of symbiosis known as mutualism, where both organisms benefit and neither is harmed.

The larger organism gained excess ATP provided by the "protomitochondrion" or excess sugar provided by the "protochloroplast", while providing a stable environment and as well as raw materials required for endosymbiosis to work out.

Over time the relationship became permanent, giving rise to double-membrane chloroplast and mitochondria organelles.

**FYI - Endosymbiotic Theory**

Supporting Evidence for Endosymbiosis is based on the shared characteristics of both chloroplasts and mitochondria:
- They contain their a simple DNA molecule that has a different code than the DNA found in the nucleus
- They are able to initiate division on their own without direction from the nucleus
  - This allows eukaryotic cells to produce more mitochondria if the demands for ATP (cellular energy) increase
  - Ex. Training muscle results in increased numbers of mitochondria in muscle cells
- Plant cells produce more chloroplasts if they need to increase the amount of glucose they are producing in photosynthesis
- They contain tiny ribosomes so they are able to make simple protein molecules using their DNA code

**Generalized Eukaryotic Cell:**

The plasma membrane is a **phospholipid bilayer** that encloses the cytoplasm and surrounds most organelles in the cell

It is composed of **Phospholipids, Proteins and Cholesterol**

The membrane is **selectively permeable** to allow necessary materials to enter and leave cells

Proteins are anchored in the membrane to allow transport of molecules and signalling to other cells.
Plasma Membrane

The plasma membrane has a **fluid mosaic model**, where the components shift and change over time based on the cell’s environment.

Plant cell membranes don’t have Cholesterol

Cholesterol is in eukaryote cell membranes to stabilize the **membrane fluidity**. Cholesterol also prevents phospholipids from getting too close together as the temperature drops, so the presence of cholesterol lowers the temperature required for the membrane to solidify (freeze)

Plant and animal cell plasma membranes are structurally similar in all ways except that plant cell membranes do not require cholesterol. This is likely due to the **rigid cell wall** that surrounds the phospholipid bilayer in plant cells! Since plant cells do not have cholesterol to prevent freezing they are more sensitive to damage from lower temperatures than animal cells.

Nucleus and Nucleolus

The nucleus contains the cells’ DNA, it is the ‘**control center**’.

**DNA is deoxyribonucleic acid.** It is the genetic code for the organism. DNA has a unique sequence of nitrogen bases (A, T, G and C) which form genes. Each strand of DNA is very long and is wrapped around proteins called **histones** to form compacted **chromosomes**.

DNA is translated into **RNA** which is the messenger form. RNA is transported out of the nucleus to other parts of the cell through **nuclear pores** in the nucleus’ membrane.

The **nucleolus** is the center part of the nucleus which synthesizes ribosomes which are then transported to the cytoplasm to make proteins.

Nucleus and Nucleolus

The nucleus is contained by a membrane called the **nuclear envelope**. It does NOT entirely enclose the nucleus.

Proteins in the nuclear envelope create large channels called pores which RNA and ribosomes can travel out of the nucleus.
Ribosomes - “Protein Factories”

Ribosomes produce proteins.

Each ribosome is made up of two subunits that join together to read a RNA molecule and produce a strand of protein.

Most ribosomes are attached to the surface of the **Rough Endoplasmic Reticulum (RER)**. Some float freely in the cytoplasm.

**Ribosomes**

This TEM of a section of a cell shows many ribosomes, both free (in the cytoplasm) and bound (to the endoplasmic reticulum).

**Bound ribosomes** make a number of important proteins that are secreted from the cell including the hormones and enzymes. The presence of the ER membrane makes it easy to packaged proteins for export from the cell.

**Free ribosomes** mainly make proteins that function inside the cell.

**Endoplasmic Reticulum (ER)**

The Endoplasmic Reticulum (ER) is a membrane enclosed system of folded channels that is attached to the nucleus and extends into the cytoplasm.

Cells have **Smooth ER (SER)** and **Rough ER (RER)**.

Both types of ER produce vesicles that ‘bud off’ along its edges to transport contents to another part of the cell or out of the cell.
Endoplasmic Reticulum

<table>
<thead>
<tr>
<th>Smooth ER</th>
<th>Rough ER</th>
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<tbody>
<tr>
<td>No ribosomes</td>
<td>Ribosomes attached to membrane</td>
</tr>
<tr>
<td>Synthesizes non-protein molecules (ex. Phospholipids, steroids)</td>
<td>Produces proteins</td>
</tr>
<tr>
<td>Packages molecules into vesicles</td>
<td>Packages proteins into vesicles</td>
</tr>
<tr>
<td>Tubular, circular structure</td>
<td>Flattened sac-like structures (called &quot;Cisternae&quot;)</td>
</tr>
<tr>
<td>Joins the RER to the Golgi Apparatus</td>
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<tr>
<td>Detoxifies cells from harmful substances (ex. alcohol, drugs)</td>
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**Golgi Apparatus**

The Golgi Apparatus functions in shipping and receiving essential molecules from the ER to other parts of the cell or out of the cell. It is composed of flattened membrane sacs that are stacked like pancakes with smaller, associated storage and transport vesicles. Each sac is not connected to the next, but transport contents through vesicles.

The Golgi is normally positioned between the ER and the plasma membrane.

‘Packages’ received are modified into final functional forms and repackaged into a vesicle.

Vesicles are ‘tagged’ to control where the package needs to go to.

**Enzymes in the smooth ER** of the liver modify or **detoxify chemicals** such as drugs, alcohol, pesticides and carcinogens by chemically converting them into more water-soluble, products that can be excreted from the body.

Being exposed to increased amounts of such compounds results in production of a **large amount of the smooth ER in liver cells** which specialize in detoxification.

Similarly, SER produces steroids, so in **Testosterone-secreting cells** (ex. testis) there is a large amount of SER.
Golgi Apparatus

Direction of vesicle transport is controlled by Cis or Trans

The **Cis** face of the Golgi is closest to the nucleus

* cis means ‘same’

Vesicles are directed to **fuse** with the Cis Golgi “receiving”

The **Trans** face of the Golgi closest to the plasma membrane

* trans means ‘opposite’

Vesicles are directed to **bud off** from the Trans Golgi “shipping”

Mitochondria - “ATP Powerhouse”

The mitochondria is the site of **aerobic cellular respiration** (metabolism) which uses oxygen and glucose to produce energy for the cell in the form of **ATP (adenosine triphosphate)**

Mitochondria are surrounded by a **double-layered membrane** and contain their own DNA and ribosomes (can produce own proteins and replicate independently of the cell)

The inner membrane is folded to increase surface area

The inner space is called the matrix
**Lysosomes**

Specialized membrane enclosed vesicles that are formed budding off of the Golgi apparatus.

Site of intracellular digestion

Contain digestive enzymes to break down nutrients or old cellular components into small molecules:

**Phagocytosis** - “Eating-cell” - the process by which the cell takes in nutrients from the environment

**Autophagy** - “Self-eating” - the process where lysosomes digest (breakdown) cellular parts

All cells are genetically programmed to die, this is called **Apoptosis**. Lysosomes are used to digest cellular components which can be reused by new cells.

**Did You Know?**

Apoptosis is used during embryonic development to shape the fetus into normal structure.

Ex. removal of tail, webbing
**Peroxisomes**

Round single-membrane enclosed organelles containing enzymes that break down toxins into harmless molecules.

They contain the enzyme **catalase** which breaks down toxic **hydrogen peroxide** into water and oxygen

\[2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2\]

Liver cells, which detoxify the body, contain many peroxisomes

Peroxisomes also breakdown other toxins, such as **free-radicals**, formed during metabolism (cellular respiration in mitochondria and photosynthesis in chloroplasts)

They are located near the mitochondria (and chloroplasts) to receive their toxic by-products.

**Vacuoles and Vesicles**

**Vacuoles** are membrane-bound organelles used to store molecules in the cell. (ex. nutrients, toxins, pigments, water, wastes ect)

Protists (Amoeba and Paramecium) have **contractile vacuoles** to expel water and **food vacuoles** to store food molecules until they can be digested into nutrient molecules by lysosomes.

Plants store pigments and starch (energy) in vacuoles. They have large centrally located water vacuoles

**Vesicles** are small vacuoles that transport molecules around, in or out of the cell

Vesicles form from budding-off of Golgi apparatus, ER or plasma membrane

**Vacuoles and Vesicles**

**Plant cells have large central vacuoles**

- Stores water, minerals and sap that the plant uses as a reservoir when water in the environment is limited
- Has a special membrane called a **tonoplast** which regulates the uptake, storage and release of waters and ions from the vacuole
**Vacuoles and Vesicles**

Vesicles are used for transport of cell materials between ER, Golgi apparatus and plasma membrane.

**Cytoplasm**

Cytoplasm is the liquid filling the space inside the plasma membrane.

- It suspends the cellular components and supports cellular shape and movement.
- It is a solvent for molecules required for metabolism and important cellular functions such as:
  - Ions (Sodium, Calcium)
  - Gases (Oxygen and Carbon Dioxide)
  - Nutrients (Glucose, Amino Acids)

**Cytoskeleton**

A network of protein filaments that exist within the cytoplasm to provide:
- Cell shape
- Organelle movement and placement
- Guide DNA during cell division

3 parts of the cytoskeleton:
1. **Microtubules**
2. **Microfilaments** (actin)
3. **Intermediate Filaments**

**Cytoplasm - Microtubules**

Microtubules are made up of Tubulin molecules.

They form sturdy tubes that make up cilia, flagella and spindle fibres.

- **Cilia and Flagella** are outer cell structures and have a $9+2$ doublet tube structure.
- **Spindle Fibres** pull DNA (chromosomes) apart during cell division and have a $9$ triplet tube structure.
Cilia and Flagella

9+2 doublet structure

Epithelial cells that line the airways in humans have numerous cilia projections.

Cilia and Flagella have different types of motion:

- Propeller-like motion
- Back and forth beating

Dynein and Kinesin are specialized motor molecules that use ATP to move:

a. Microtubules along each other (Cilia and Flagella movement)
b. Cellular components along microtubules
**Spindle Fibres - Centrioles and Centrosomes**

During cell division **centrioles and centrosomes** are formed from microtubules to assist in separating the chromosomes (DNA) into the new cells.

A pair of centrioles at each pole of the cell (oriented at right angles to each other) produce **Spindle Fibres** that attach to the DNA (chromosomes).

**Cytoskeleton - Microfilaments**

Microfilaments are made up of **actin molecules**

Microfilaments are more dynamic (changing) than other cytoskeleton parts.

**Actin filaments** make up the internal cytoskeleton of the cell to give it shape

*Ex. Movement of internal structures
Movement of unicellular/motile cells
Change of shape during cellular division*

In plant cells parallel Actin filaments 'squeeze' cytoplasm forwards = **cytoplasmic streaming**

When a cell divides the **cleavage furrow** is formed by a contracting ring of actin filaments in the center of the division.
Cytoskeleton - Intermediate Filaments

Intermediate Filaments are made up of twisted fibrous protein cables.

They are stable structures that anchor cell organelles in place.

Animal Cell Junctions

Three types:
1. Tight Junctions
2. Adhering Junctions (also called Desmosomes)
3. Gap Junctions
Animal Cell Junctions - Tight Junctions
Sections of the outer membrane where two neighbouring cells are fused together
Composed of protein and create a leak-proof barrier between cells
Ex. Cells lining the digestive tract are joined by tight junctions to ensure that enzymes and digestive juices do not leak into the abdominal cavity

Animal Cell Junctions - Adhering Junctions
(also called Desmosomes)
Composed of dense plaques of strong, fibrous protein to hold neighbouring cells together and anchor cytoskeleton components
Act like ‘weld spots’ to provide support for tissues that undergo constant stress
Ex. Cardiac muscle cells which constantly contract and relax

Animal Cell Junctions - Gap Junctions
Composed of connexon protein channels that allow ions, nutrients and small molecules to pass freely between cells
Also allow transfer of electrical impulses from one cell to the next (ex. Cardiac muscles)
Makes cell communication fast and efficient
Plant Cells

**NOT in plant cells:**
- Lysosomes
- Centrioles
- Flagella

### Plant Cell Walls

**Plant Cell Walls**

Composed of **cellulose** (carbohydrate molecule composed of glucose molecules)

When formed a **primary cell wall** is built first. It is flexible to allow for cell growth.

A **secondary cell wall** is constructed within the primary wall once growth is complete.

The secondary wall is rigid and strong.

A **middle lamella** is a glue-like substance (**pectin**) that forms between two adjacent cells.

### Plant Cell Junctions - Plasmodesmata

**Plasmodesmata** are plant cell junctions that allow continuous exchange of cytoplasm and cell materials between cells.
**Chloroplasts**

The site of **photosynthesis**; the reactions which produce glucose

Has a **double layered membrane**, contains its own DNA, ribosomes and can self-replicate in the cell

The inner membrane is folded to form **granum** which resemble stack of coins - each 'coin' is called a **thylakoid**

The interior of the organelle is filled with **stroma** which is similar to cell cytoplasm

The inner membrane contains light-capturing pigments, such as **chlorophyll** which give plants their characteristic green colour

**FYI - Leucoplasts and Chromoplasts**

Specialized types of membrane-bound plastid found in plant cells and algae

**Leucoplasts**: stores starch granules, a product of photosynthesis

**Chromoplasts**: stores pigments, other than chlorophyll
Identify the parts of the Plant Cell that are not in animal cells.