CELL BIOLOGY

Eukaryotes have a much more complex cell structure than prokaryotes

Eukaryotic cell - Animal cell

A cell whose nucleus is enclosed in a membrane.

Prokaryotic cell - Bacteria

A cell that lacks organelles or other internal membrane bound structures

Surface area to volume ratio is important in the limitation of cell size.

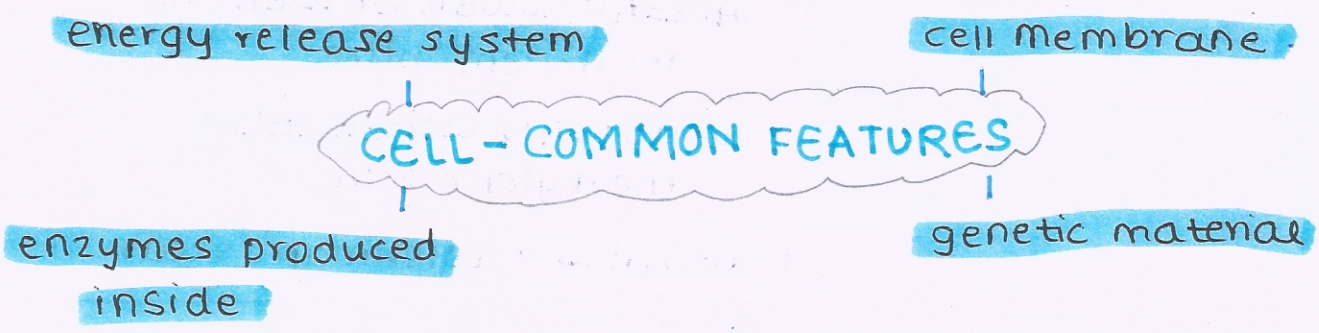
Specialized tissues can develop by cell deferentiation in multicellular organisms.

Differentiation

It is a process where a cell changes from one cell type to another. It envolves the expression of some genes and not others in a cell genome.

THE CELL THEORY

This states that cells are the fundamental building blocks of all living organisms. The smallest organisms are unicellular organisms - they consist of one cell. Larger organisms are multicellular organisms - they are composed of many cells.



Discrepancies

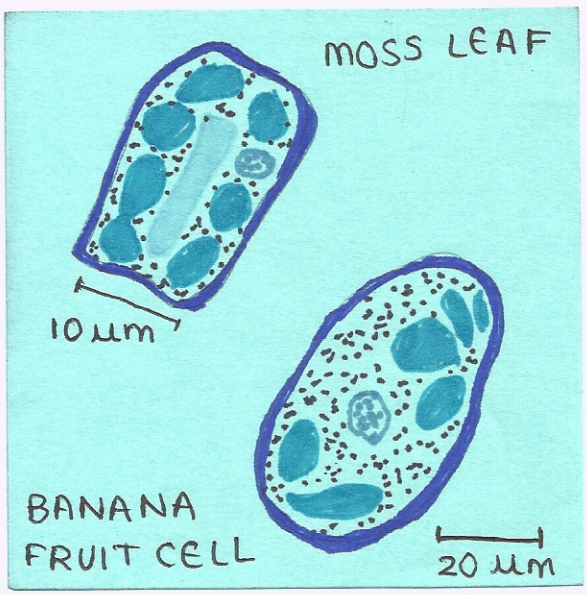
The exceptions found to a general trend. Scientists have to judge whether the discrepancies are common or serious enough to make predictions too unreliable to be useful. The theory is then discarded.

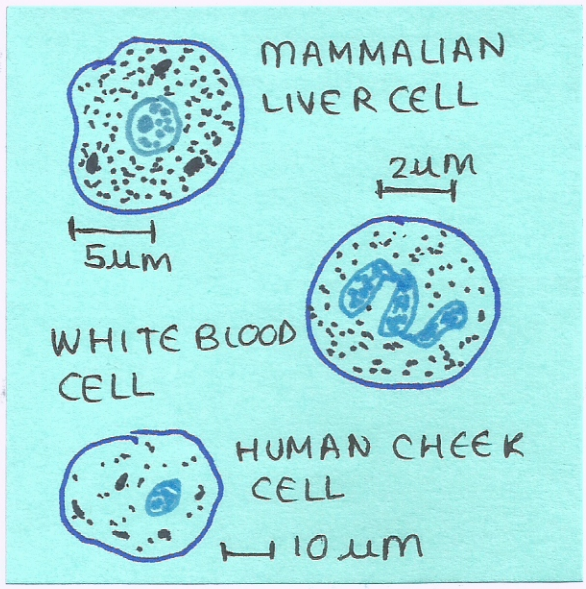
ROBERT HOOKE

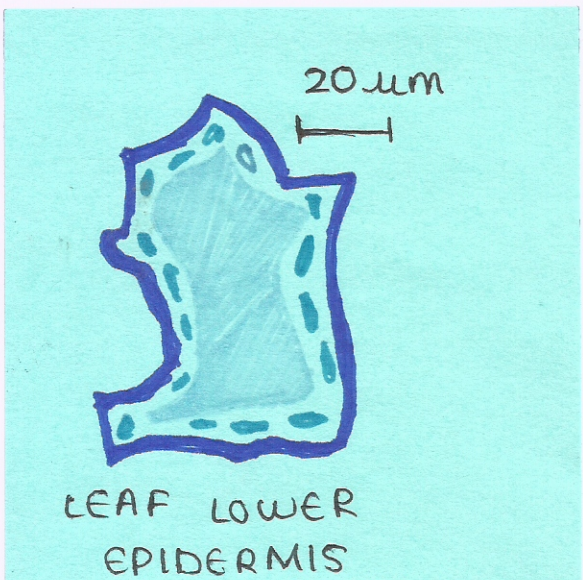
→ the first person to use the word cell for structures in living organisms.

→ 1665 after examining cork and other parts of the plant, he discovered cells.

PLANT AND ANIMAL CELL DRAWINGS







1. MOSS LEAF - methylene blue
2. BANANA FRUIT CELL - iodine sol.
3. MAMMALIAN LIVER CELL - methylene blue
4. LEAF LOWER EPIDERMIS - methylene blue
5. HUMAN CHEEK CELL - methylene blue
6. WBCs - Leishman's stain

CALCULATION OF MAGNIFICATION & ACTUAL SIZE

School microscope - 3 levels of magnification:

- x40 (low power)
- x100 (medium power)
- x400 (high power)

FORMULA → To find the magnification of a micrograph or a drawing.

$$\text{magnification} = \frac{\text{size of image}}{\text{actual size of specimen}}$$

- The units for the size of the image and actual size of the specimen are the same. Both could be in mm (millimeters) or (μm) micrometers.

Millimeters can be converted to micrometers by multiplying by one thousand (1000).

Micrometers can be converted to millimeters by dividing by one thousand (1000).

Scale bars

They are generally put on micrographs or drawings. These are just straight lines, with the actual size that the scale bar represents.

Example: Length of an image is 30mm. It represents a structure that has an actual size of 3 μm. Determine the magnification.

$30\,mm = 30 \times 10^{-3}\,m$

$3\,\mu m = 3 \times 10^{-6}\,m$

$$\text{magnification} = \frac{30 \times 10^{-3}}{3 \times 10^{-6}} = 10{,}000\times$$

LIMITATIONS ON CELL SIZE

Surface area to volume ratio is important in the limitation of cell size and in relation to heat.

The rate of the reactions taking place in the cell is directly proportional to the volume of the cell.

Substances used in the reactions must be absorbed by the cell and waste products must be removed so that the process of metabolism continues.

Process

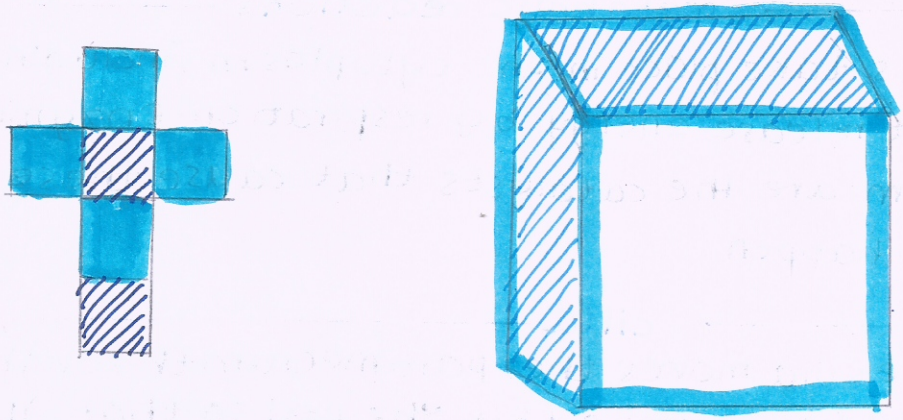
Substances move into and out of our cells through the plasma membrane at the surface of the cell.

The rate at which substances cross this membrane depends on its surface area.

If the ratio of surface area to volume is small,

- the substances won't enter the cell as quickly as they are required and waste products will accumulate because they are produced more rapidly than they can be excreted.
- the cells may over heat because the metabolism produces heat faster than it is lost over the cell's surface.

RATE OF REACTIONS $\propto$ VOLUME OF CELL



Volume and surface area of a Cube.

FUNCTIONS OF LIFE IN UNICELLULAR ORGANISMS

1. PARAMECIUM

Nucleus

- The nucleus of the cell can divide to produce the extra nuclei that are needed when the cell reproduces. Often the reproduction is asexual with parent cell dividing to form 2 daughter cells.

Food vacuoles

- Food vacuoles contain the smaller organisms that the Paramecium has consumed. They are gradually digested and the nutrients are absorbed into the cytoplasm where they provide energy and materials needed for growth.

cell membrane

- It controls what chemical enters and leaves. It allows the entry of oxygen for respiration. Excretion happens simply by waste products diffusing out through the membrane.

Contractile vacuoles

- Contractile vacuoles at the each end of the cell fill up with water and then expel it through the plasma membrane of the cell, to keep the cell's water content within tolerable limits.

metabolic reactions

- These reactions take place in the cytoplasm, including the reactions that release energy by respiration. Enzymes in the cytoplasm are the catalysts that cause these reactions to happen.

cilia

- Beating of the cilia moves the paramecium through water and this can be controlled by the cell so that it moves in a particular direction in response to changes in the environment.

Testing the cell theory

3 examples worth considering:

1. Striated muscle

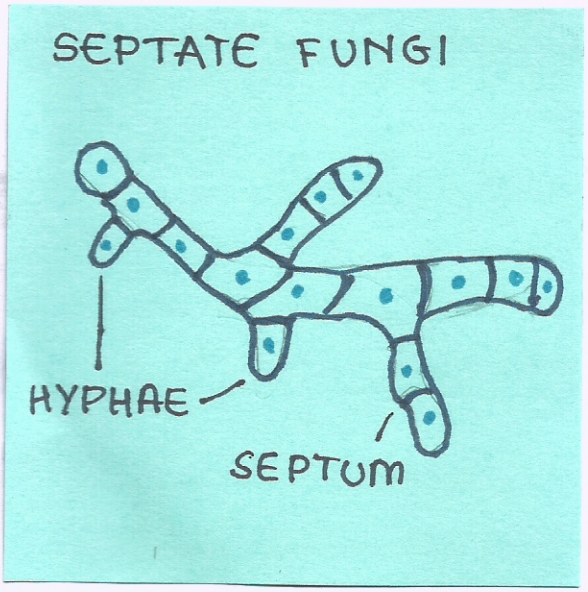
- we use this tissue to change the position of our body.
- building blocks of this tissue are muscle fibres.
- surrounded by a membrane
- formed by division of pre-existing cells.
- own genetic material and energy release system

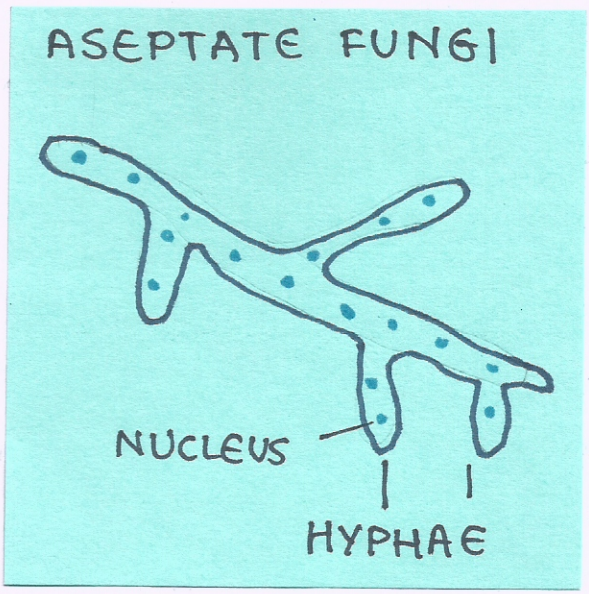
2. Fungi

- consist of narrow thread-like structures called **hyphae**.

APPEARANCE OF HYPHAE

- white in colour
- have a cell membrane and a cell wall.
- fluffy appearance
- In some type of fungi the hyphae are divided into small cell like sections by cross walls called **septa**.
- In **aseptate** fungi there are no septa.
- **Hypha** is an uninterrupted tube like structure with many nuclei spread around it.





3. Algae

- feed themselves by photosynthesis
- store their genes inside nuclei
- simpler in their structure and organisation than plants.
- consist of one microscopic cell.
- oceans contain a lot of unicellular algae in oceans
- form the basis of most marine food chains.
- Some algae grow to a much larger size and are called giant algae. Example: Acetabularia.
  - it can grow to a length of as much as 100 mm.
  - has one nucleus only

UNICELLULAR ORGANISMS

organisms consisting of only one cell carry out all functions of life in that cell.

Because the unicellular organisms have only one cell that carries out all functions of life, it is more complex in its structure than the cells in multicellular organisms.

Seven functions of life carried out by them:

1. Nutrition - obtaining food to provide energy and materials needed for growth.
2. Metabolism - chemical reactions inside the cell, including cell respiration to release energy.
3. Growth - an irreversable increase in size.
4. Response - the ability to react to changes in the environment
5. Excretion - getting rid of the waste products of metabolism.
6. Homeostasis - keeping conditions inside the organism within tolerable limits.
7. Reproduction - producing offspring either sexually or asexually.

MULTICELLULAR ORGANISMS

They have properties which emerge from the interaction of their cellular components.

Organisms consisting of a single mass of cells, fused together are multicellular.

EXAMPLE: Caenorhabditis elegans (worm)

- they have no common name
- live in decomposing organic matter
- feeds on the bacteria that cause decomposition.
- has a mouth, pharynx, intestine and anus.
- hermaphrodite → male and female reproductive organs
- 1/3rd cells are neurons or nerve cells.
- neurons are located at the front end of the worm.
- the brain co-ordinates responses to the worm's environment but does not control how individual cells develop.

Co-operative groups

without any cells in the group acting as a leader.

Emergent properties

Individual cells can organize themselves and interact with each other to form a living organism with distinctive overall properties. The characteristics of the whole organism, including the fact that it is alive are called emergent properties.

- They arise from the interaction of the component parts of a complex structure.

CELL DIFFERENTIATION

Specialised tissues can develop by cell differentiation in multicellular organisms.

Division of labour

Different cells perform different functions. This is called division of labour.

Example:

RBCs → carry oxygen

rod cell in retina → absorb light and transmit impulses to brain.

TISSUE:

Group of cells specialize in the same way to perform the same function. They are called a tissue.

- Cells in a tissue can carry out their role more efficiently as they are specialized.
- They can develop the ideal structure, with the enzymes needed to carry out all of the chemical reactions associated with the function.

Differenciation

The development of cells in different ways to carry out specific functions is called differentiation.

Gene expression & CELL DIFFERENTIATION

Differentiation involves the expression of some genes and not others in a cell's genome.

- All different cell types have the same set of genes.
- The genes are present but they might not be used by the organ.
- Cells do not have genes with the instructions that they need, they have genes needed to specialize in every way.

when a gene is being used in a cell, we say that the gene is being expressed.

- the gene is switched on and the information in it is used to make a protein or a gene product. ON protein
- development of a cell → switching on particular genes and expressing them but not others.
- cell differenciation happens because a different sequence of genes is expressed in different cell types.
- control of gene expression is crucial for development.

Example: genes in humans that carry the information for making receptors for odorants.

→ These genes are only expressed in cells in the skin inside the nose, called olfactory receptor cells.

Each of these cells just express one of the gene which makes one type of receptor detect one type of smell.

This is how we can differenciate between various kinds of smells.

STEM CELLS

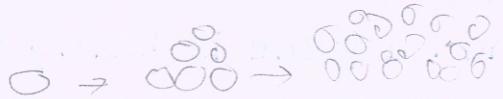
The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development.

At the early stages of embryonic development, the cells are capable of dividing many times to produce large amounts of tissue.

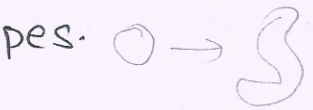
They are extremely versatile and can differenciate along different pathways into any cell types found in the animal.

The name stem cells was given to the zygote and the cells of an early embryo meaning that all the adult tissues come from them.

Two key properties of stem cells:



- Stem cells can divide multiple times to produce copious quantities of new cells. They are useful for the growth of tissues or replacement of cells that have been damaged.
- Stem cells are not fully differenciated. They can differenciate in different ways to produce different cell types.



NON-THERAPEUTIC USES OF STEM CELLS:

- can be used to produce large quantities of striated muscle fibres, or meat, for human consumption. The beef burgers in the future may be produced from stem cells without the need to rear or slaughter cattle.

THERAPEUTIC USES OF STEM CELLS:

Embryonic stem cells are potentially useful. They can produce regenerated tissue.

- can be used to treat type-1 diabetes where a particular cell type has been lost or is malfunctioning.
- can be used to grow whole organs for replacement such as hearts or kidneys.

Development of stem cells:

- In early stages, they are the most versatile.
- during embryonic development, they commit themselves to a pattern of differenciation.
- This involves a series of points at which a cell decides whether to develop along one pathway or another. Eventually each cell becomes commited to one cell type.
- After this, a cell may be able to divide, but all of these cells will differenciate in the same way and will no longer be stem cells.
- some cells still remain as stem cells are may be present in bonemarrow, skin and liver. They give the power of regeneration and repair

USE OF STEM CELLS IN DISEASES

Stargardt's disease

(Stargardt's macular dystrophy)

- It is a genetic disease that develops in children (ages - 6 to 12).
- It happens due to a recessive mutation of a gene ABCA 4.
- It causes a membrane protein used for active transport in retina cells to malfunction. The photoreceptive cells in the retina degenerate.
- The experiment was done initially with mouse cells where the vision of the mouse improved.
- The cells get attached to the retina and remain there.

Leukemia (cancer)

All cancers start when mutations occur in genes that control cell division. Specific mutations must occur in these genes in one cell.

- Leukemia involves the production of abnormally large numbers of white blood cells.
- White blood cells are produced in the bone marrow and then released into the blood.

To cure leukemia, the cancer cells in the bone marrow that are producing these excessive WBCs must be destroyed.

↳ This can be done by injecting chemicals that kill these cells. The procedure is known as chemotherapy.

stem cells that can produce blood cells must be present, but they are killed during chemotherapy.

The patient should have atleast some amount of WBCs left in their body to stay healthy.

SOURCES OF STEM CELLS AND THE ETHICS OF USING THEM

Sources:

- Embryos can be deliberately created by fertilizing egg cells with sperm and allowing the zygote to develop for a few days until it has between 4 to 16 cells. These cells are embryonic stem cells.
- Blood can be extracted from the umbilical cord of a new-born baby and stem cells are obtained from it. The cells can be frozen and stored for later use in the baby's life.
- They can be obtained from some adult tissues such as bone marrow.

Properties and ethics of some stem cells:

1. Embryonic stem cells:

- unlimited growth potential
- can differenciate into any type in the body.
- more risk of becoming tumour cells than with adult stem cells including teratomas that contain different tissue types.
- less chance of genetic damage due to the accumulation of mutations than with adult stem cells.
- likely to be genetically different from an adult patient receiving the tissue.
- Removal of cells from the embryo kills it, unless only one or two cells are taken.

2. Cord blood stem cells

- easily obtained and stored
- commercial collection and storage services already available.
- fully compatible with the tissues of the adult that grows from the baby, so no rejection problems.
- limited capacity to differenciate into different cell types - only naturally develop into blood cells.
- limited quantity from one baby's chord.
- The umbilical cord is discarded whether or not stem cells are taken from it.

3. Adult stem cells

- Difficult to obtain as there are very few and are buried deep in tissues.
- less growth potential than embryonic stem cells.
- less chance of malignant tumours developing than from embryonic stem cells.
- Limited capacity to differenciate into different cell types.
- Fully compatible with the adult's tissues, so no rejection problem.
- Removal does not kill the adult from which the cells are taken.