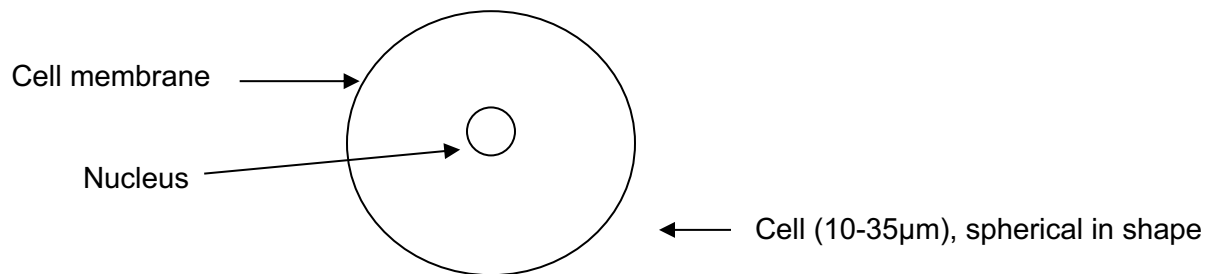


A2.2 Cell structure

Cells as the basic structural unit of all living organisms

Atoms → Molecules → Cells (Fundamental Unit of Life)



Cells → Tissues → Organs → Organ systems → Organisms

Tissue: A group of similar cells, which perform a specific function. Each type of tissue has a different function

Organs: A structural & functional unit comprised by a number of tissues, performing a variety of functions

Organ systems: Organs functioning in groups (eg. Digestive system)

THE IMPORTANCE OF CELLS

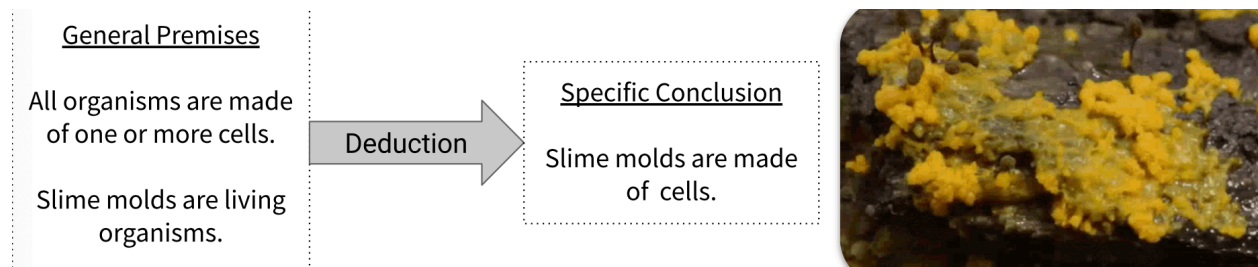
- All living organisms are composed of cells (uni- multicellular)
- New cells (daughter) are derived from parental cells
- Cells contain the hereditary material (DNA) of an organism passed from parent to daughter cells
- All metabolic processes take place within cells

Inductive VS deductive reasoning

The cell theory is based on observations. Theories developed from observations are an example of **inductive reasoning**, using specific observations to form a general conclusion.

The cell theory can be used to make predictions using **deductive reasoning** → using a general premise to form a specific conclusion:

Example



The word THEORY in the cell theory

In daily use: a theory is a guess, there is a doubt

In scientific use: a theory has been shown to be true through repeated observations and experiments. There is no current doubt. As of yet, no evidence has been collected that does not support the idea.

- Outline how deductive reasoning can be used to predict characteristics of a newly discovered organism.

Microscopy:

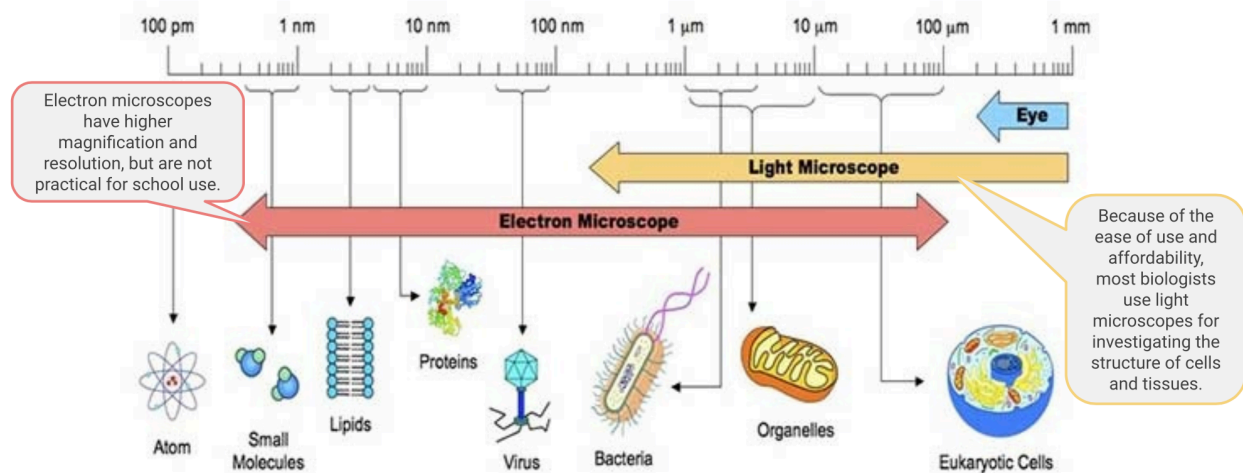
Magnification

→ How much larger an object appears compared to its real size (light microscopes)

Resolution

→ The smallest interval distinguishable by the microscope in great detail (electron microscopes)

Microscopes are devices that produce a magnified image of objects too small to be seen directly by eyes. Developments in microscopy have led to discoveries in biology ([A2.2.3](#)).



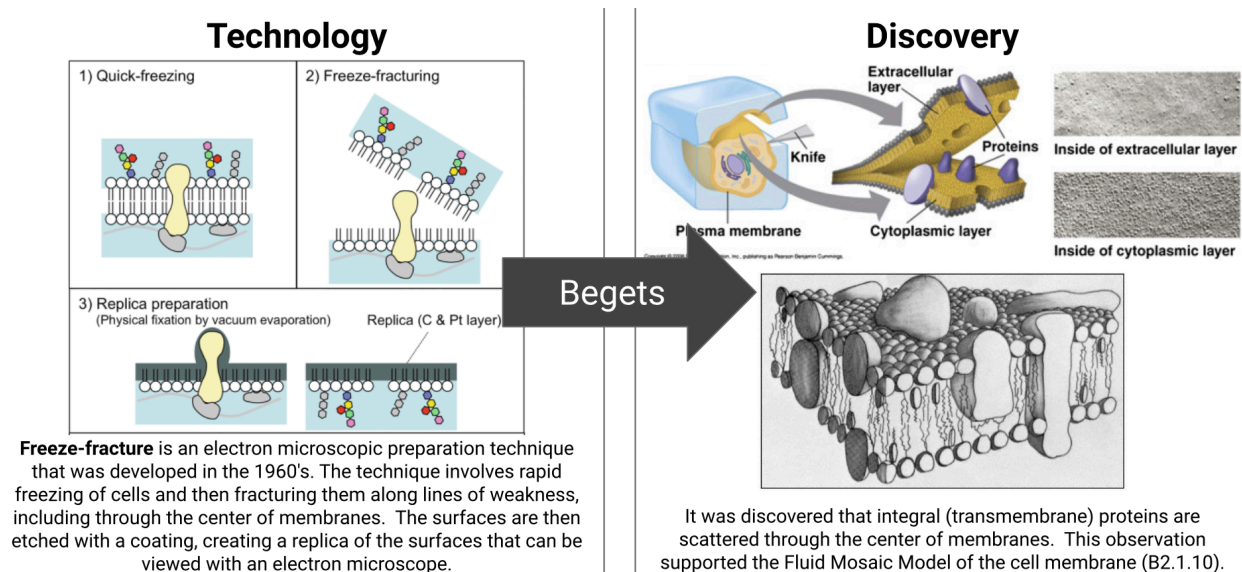
The use of fluorescent stains and immunofluorescence

Stains are colored substances that bind to specific chemicals and generate a particularly bright image.

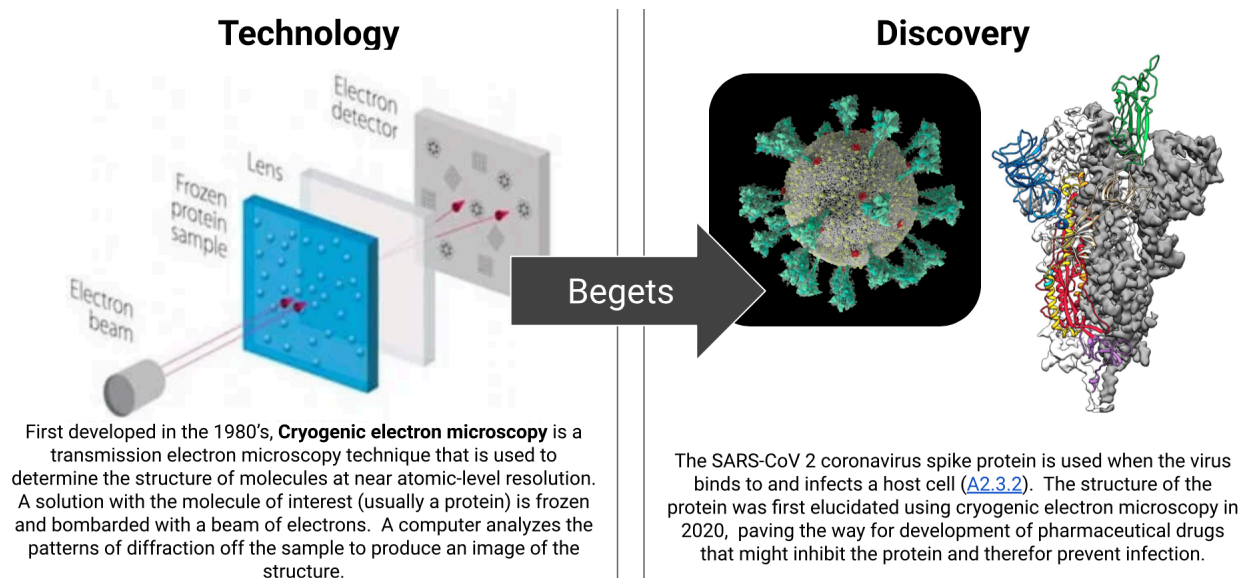
Immunofluorescence is a technique that uses fluorescently stained antibodies to bind to specific proteins within a cell. That protein can be tracked if it moves in the cell (1942).

Electron microscopy:

a) Freeze-fracture electron microscopy

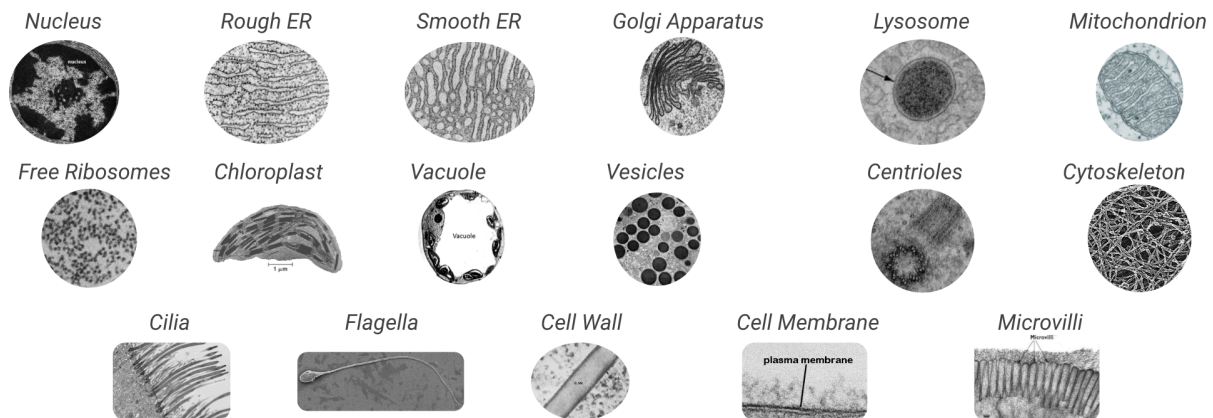


b) Cryogenic electron microscopy



*begets = brings about, gives rise to

Eukaryotic cell micrographs:



Calculating Magnifications

→ Magnification = size of image / actual size of specimen

1. Choose an obvious length, for example the maximum diameter of a cell. Measure it on the drawing
2. Measure the same length on the actual specimen
3. Convert units
4. Divide the length on the drawing by the length on the actual specimen. The result is the magnification

Example:

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

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

$$3 \mu\text{m} = 3 \times 10^{-6} \text{ m} \rightarrow \text{Magnification} = 30 \times 10^{-3} / 3 \times 10^{-6} = 10,000 \times$$

Or: 30 mm = 30,000 μm → Magnification = 30,000 / 3 = 10,000 x

Prokaryotic cells

Prokaryotic cells do not have a distinct nucleus and organelles. The only prokaryotic cells are **bacteria** and blue-green bacteria (cyanobacteria).

Figure 1: Generalized structure of a prokaryotic cell

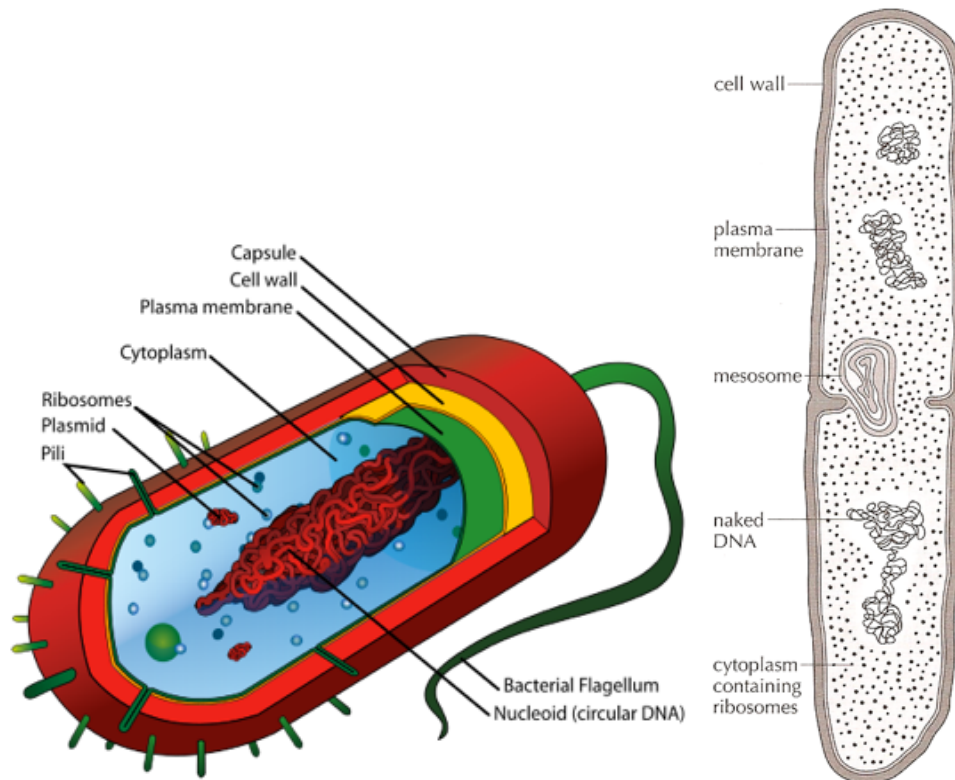


Table 1: Description of the structure and function of a prokaryotic cell

Structure	Function
Cell wall	Protection from bursting, maintenance of shape
Plasma membrane	Controls entry and exit of substances
Mesosome	Increases the surface membrane for ATP (energy) production
Naked DNA	Stores the genetic information that controls the cell
Cytoplasm	Mostly liquid (cytosol), contains catalytic enzymes, sugars, proteins needed to carry out metabolic processes
Ribosomes	Help protein synthesis (translation of DNA)
Nucleoid	The region in the cytoplasm where the DNA is found
Capsule	Helps cell avoid dehydration and adhere to surfaces

Some prokaryotic cells such as *E. coli* also have an extra structure called **flagellum**: Appendages that are used for locomotion.

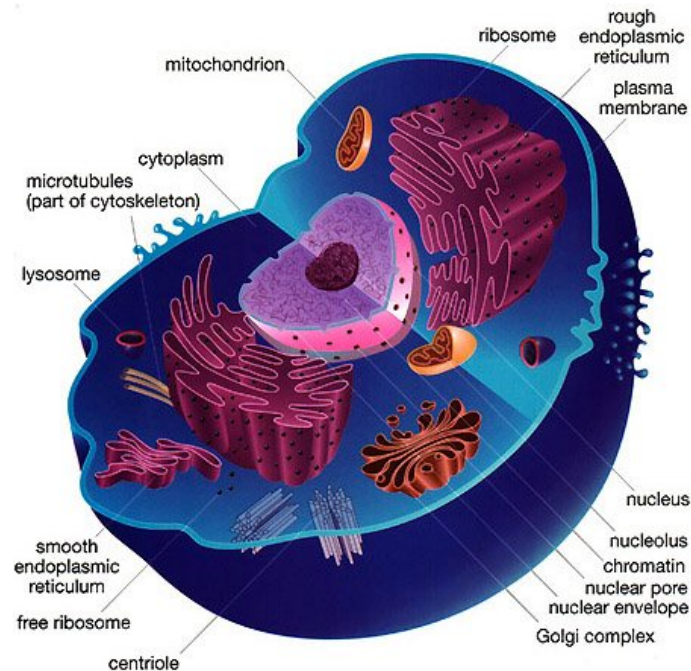
Pilli: a long “fibre” that links two bacterial cells for the exchange/transfer of DNA. They can be used to pull cells together.

Prokaryotic activities

- **Photosynthesis:** blue - green bacteria make their own food by ph/s
- **Nitrogen fixation:** N-fixing bacteria convert N from the air into other nitrogenous compounds
- **Fermentation:** conversion of a substance into a different form for e.g. milk into yoghurt.

Prokaryotic cells divide by **binary fission** i.e. one cell being capable of giving rise to over 4×10^{21} cells in 24 hrs. The single circular chromosome is replicated and the two copies of the chromosome move to the opposite ends of the cell. Division of the cytoplasm of the cell quickly follows.

Generalized structure of a eukaryotic cell



Structure	Function
Cell membrane	Responsible for the entry and exit of substances
Ribosomes	Protein synthesis (Translation of DNA). They are “free” or “bound”
Mitochondria	Aerobic cell respiration (ATP)
Nucleus	Holds chromosomes, control centre of the cell
Rough endoplasmic reticulum	Synthesis of proteins that will be secreted
Lysosomes	Hold digestive enzymes, breaks-down harmful substances inside the cell
Golgi Apparatus	Processing/ modification of proteins brought in vesicles from the rER
Microtubules	Used for the transport of organelles and the separation of chromosomes during mitosis
Centrioles	Anchor points for microtubules
Cilia and flagella	Cilia are short and numerous. Flagella are long and few

Comparison of animal eukaryotic and prokaryotic cells (bacteria)

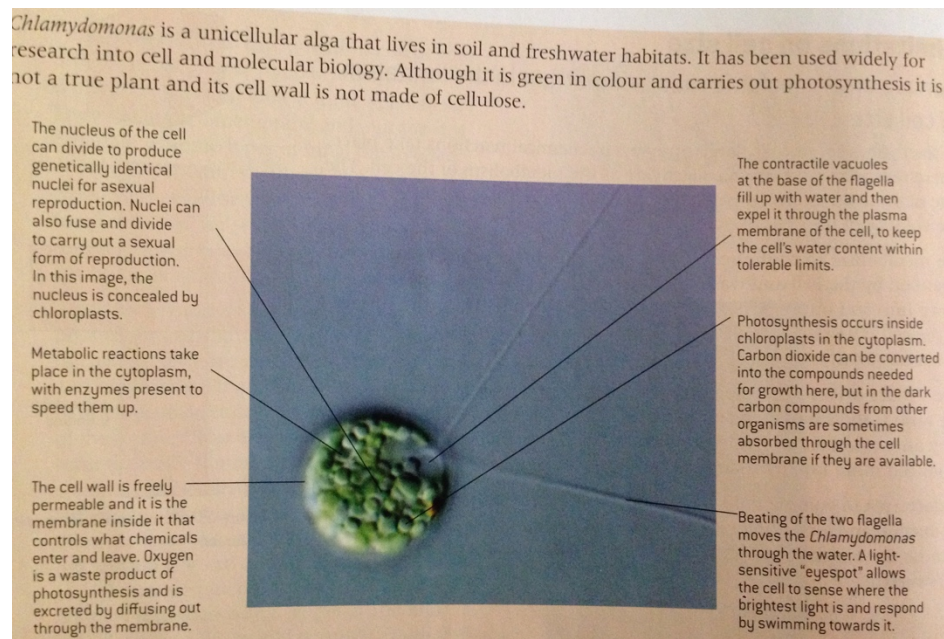
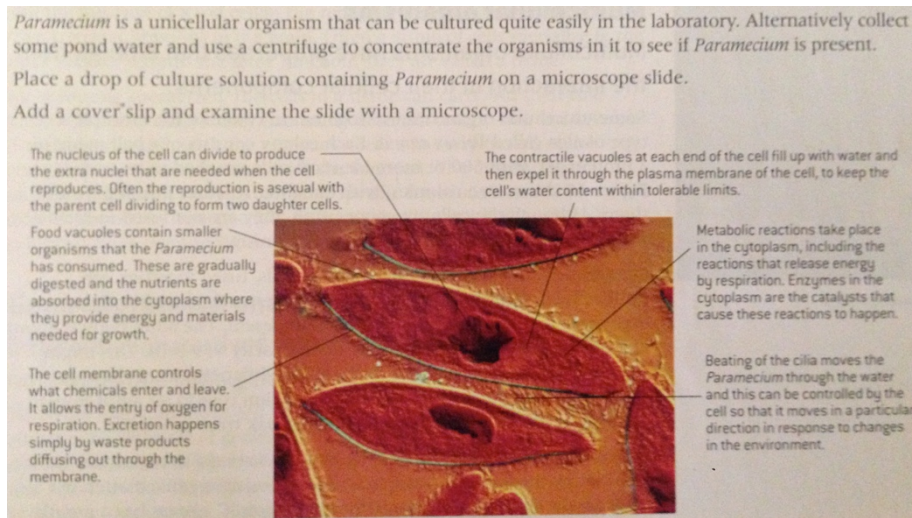
Feature	Eukaryotic	Prokaryotic
Cell wall	No	Yes
Shape	Rounded	Regular (square), elongated
Size of ribosomes	80 S	70 S
Organelles	Yes	No
Nucleus	Membrane bound	Naked DNA

Comparison between eukaryotic plant, animal and fungal cells

Feature	Animal	Plant	Fungi
Cell wall	No	Yes	Yes (chitin)
Photosynthesis	No	Yes	No
Carbohydrate storage	Glycogen (glu + glu+glu)	Starch (glu + glu+glu)	
Vacuole	Not really!	Yes	Yes
Chloroplast	No	Yes	No
Ribosomes	80S	80S	80S
Plastids (manufacture and store food)	No	Yes	No
Centrioles	Yes (for cell division)	Yes (in male gametes)	No
Cilia / flagellum	Yes	Yes	No

Fungi are eukaryotic (uni or multicellular) that have a cell wall, some are parasitic or decomposers.

Uni-cellular organisms: Carry out all functions of life (eg amoeba) such as nutrition, reproduction, growth, metabolism, secretion, homeostasis, response and sometimes movement.



Multi-cellular organisms: Each group of cells carries out specialized functions (eg animals). This means that multi-cellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others (differentiation).

<https://www.youtube.com/watch?v=hjTdbWblhxw&t=19s>

Emergent properties: A multicellular organism is more than the sum of its parts, since interactions exist between cells and group of cells!

Note: Viruses (20 – 30 nm) are NON cellular and multiply within cells. They do contain nucleic acids (DNA or RNA) surrounded by a protein coat.

Exceptions to the cell theory

- Muscle fibre cells can be longer than 300 mm long!
- Muscle cells contain hundreds of nuclei!
- Muscle cells have their own genetic material and their own energy release system
- Many algae grow to a large size but they are composed of a single cell.
- The giant algae (*Acetabularia*) can be 100 mm long and contains only one nucleus
- Fungi consist of narrow thread-like structures called hyphae. Each hypha can contain many nuclei.
- Mitochondria and chloroplasts have their own genetic material, and reproduce independently from the rest of the cell!
- Red blood cells do not have a nucleus nor mitochondria!
- The first cell did not originate from a pre-existing cell!

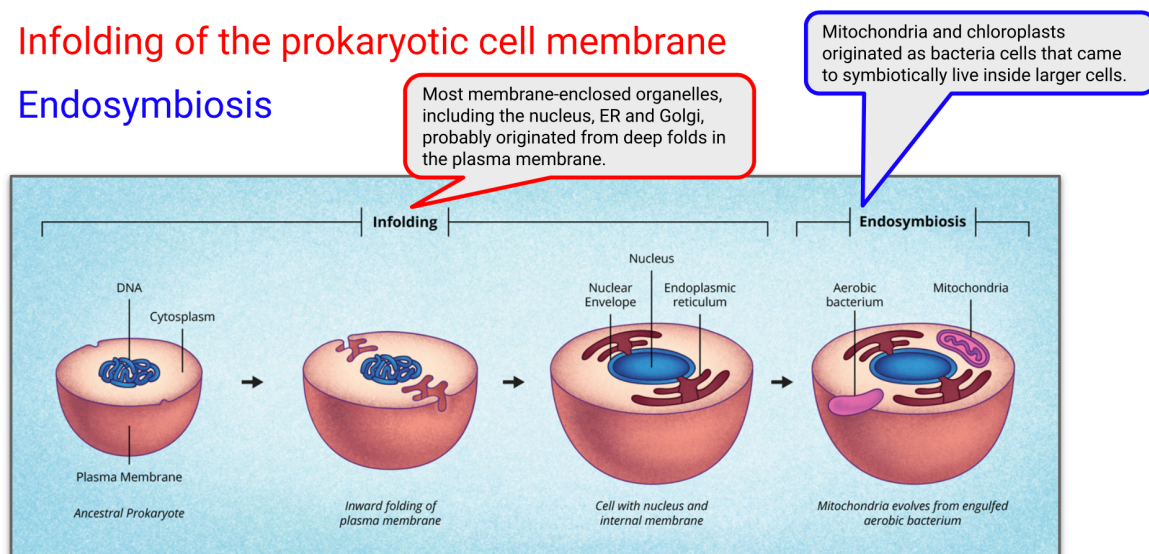
Higher Level

Origin of eukaryotic cells by endosymbiosis

Endosymbiosis states that mitochondria and chloroplasts were once free-living prokaryotic organisms able of aerobic cell respiration. Larger prokaryotes that could only respire anaerobically, took them in by endocytosis. Instead of killing and digesting the smaller prokaryotes, they allowed them to continue to live in their cytoplasm. They persisted over millions of years of evolution to become the mitochondria inside eukaryotic cells today...

Two processes are thought to have led to the origin of eukaryotes....

1. Infolding of the prokaryotic cell membrane
2. Endosymbiosis



Differentiation

→ A special type of eukaryotic cells: STEM CELLS

Stem cells have the ability to develop and form all the tissues of the body. They have the capacity of dividing and differentiating thus helping gene therapy. The best source of stem cells is from very early embryos, umbilical cord and placenta, but adult tissues e.g. bone marrow, skin and liver also contain stem cells. The rest of the stem cells allow for limited repair (eg. brain and heart). A special process called DNA methylation enables the permanent silencing of some genes!

The therapeutic use of stem cells enables scientists to improve or restore the health of patients suffering from genetic disorders (Parkinson's disease, mobility restoration, correction of immune system etc.).

An example of differentiating stem cells

Beginning with the fertilized egg, a cascade of cell differentiation (shown here in simplified form) ends up with a fully specialized blood cell. While embryonic stem cells can form almost any cell, the hematopoietic stem cells found in bone marrow and umbilical cord create various forms of blood and immune cells—and *only* those cells, most scientists now agree.

