# UNIT 4

# Cell Biology (Cytology)

# 4.1 Cell theory

## A timeline for the development of the cell theory

1. **1665** **Robert Hooke**, with one of the earliest compound microscopes, makes drawings of cork and sees tiny structures that he calls 'cells'.

- However, although his microscope is a compound microscope, the lenses are not very good and magnifications of more than30× are very blurred and do not show much detail.
- Also, Hooke saw only dead cells.





*Figure 4.3 Robert Hooke's drawing of cells in cork*

2. **1674 Anton van Leeuwenhoek** sees living, moving unicellular organisms (protoctistans) in a drop of water.

- He is using a simple microscope with only one lens. It is really little more than a magnifying glass with a mount for the specimens.
- However, van Leeuwenhoek is very skilled at grinding lenses and so his microscope can achieve magnifications of 300×.
- He calls the moving organisms 'animalcules'.
- He also sees bacteria (from his teeth),which he also calls 'tiny animalcules'.



**Figure 4.6** Anton van Leeuwenhoek



**Figure 4.5** Anton van Leeuwenhoek's microscope

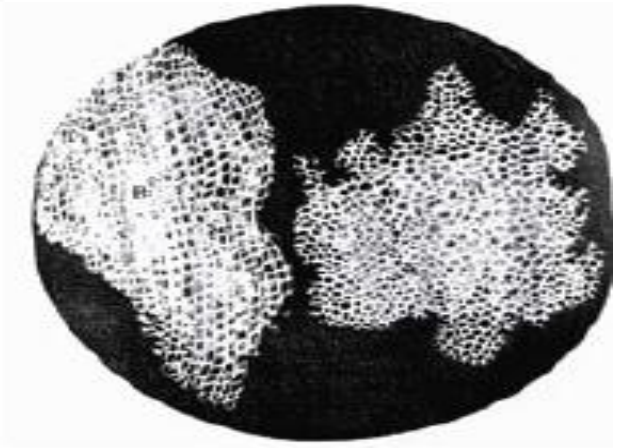


**Figure 4.3** Robert Hooke's drawing of cells in cork

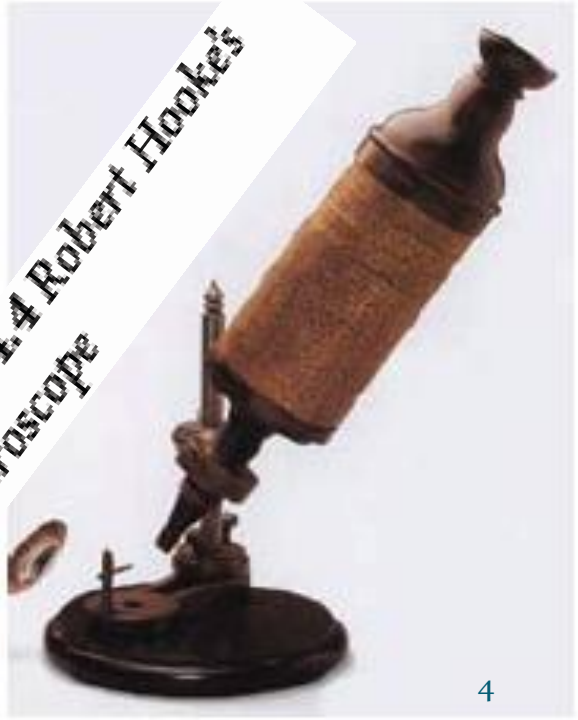


**Figure 4.4** Robert Hooke's microscope

3.1824 The French biologist **Rene Dutrochet** concludes that all organisms are composed of cells. This follows many years work in which he also discovers:

A. the stomata in the epidermis of leaves
B. the process of osmosis
C. chlorophyll is needed for photosynthesis to occur
D. respiration occurs in both animals and plants

- In many ways, Dutrochet is the man who first states the cell theory by recognising that all organisms are made of cells and that 'all growth occurs because of the increase in volume of cells or by the addition of more little cells'.

4. 1839 Matthias Schleiden and Theodor Schwann put forward the first clearly stated cell theory. It states that:

a. the cell is the unit of structure, physiology and organization in living things

b. the cell retains a dual existence as:

- a distinct entity, and
- a 'building block' in the formation of organisms

c. cells form by free-cell formation (spontaneous generation)

4. **1858 Rudolf Virchow**, a German doctor who develops many surgical techniques and promotes several fields of modern medicine, declares that: '*Omnis cellula e cellula*', whichmeans that a cell can only arise from another cell like it.

- With this he completes the first accepted version of the cell theory:

1. all organisms are made up of one or more cells
2. all cells come from pre-existing cells
3. the cell is the unit of structure, physiology and organization in living things
4. the cell retains a dual existence as a distinct entity and a building block in the construction of organisms

- Today, this has been modified and extended in the light of our increased knowledge of genetics and cell biology and now reads:

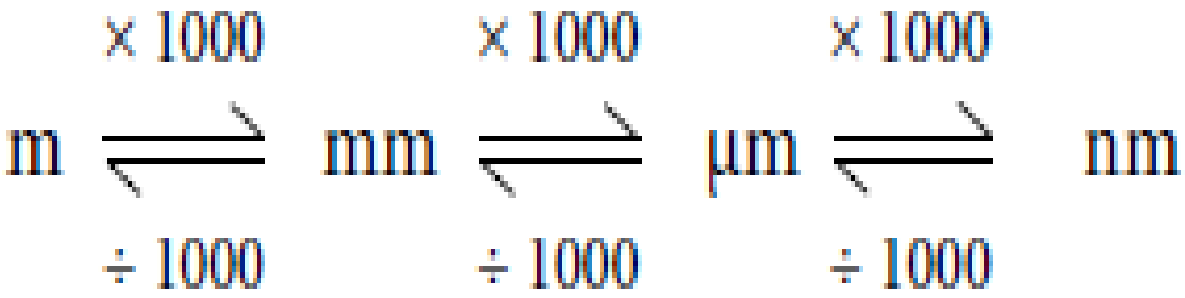
1) all known living things are made up of cells
2) the cell is a structural and functional unit of all living things
3) all cells come from pre-existing cells by division (there is no spontaneous generation of cells)
4) cells contain hereditary information which is passed from cell to cell during cell division
5) all cells have basically the same chemical composition
6) all energy flow (the metabolism and biochemistry of life)occurs within cells

# How big are cells?

## What units shall we measure cells in?

- There are three smaller units commonly used:
- millimetres (mm) =1/1000 of a metre
- micrometres (μm) = 1/1000 of a millimetre, and
  =1/1 000 000 of a metre
- nanometres (nm) =1/1000 of a micrometre,
  =1/1 000 000 of a millimetre, and
  =1/1000 000 000 of a metre

We can convert the units from one to another as shown below:




To convert a larger unit to the next smaller unit, multiply by 1000:

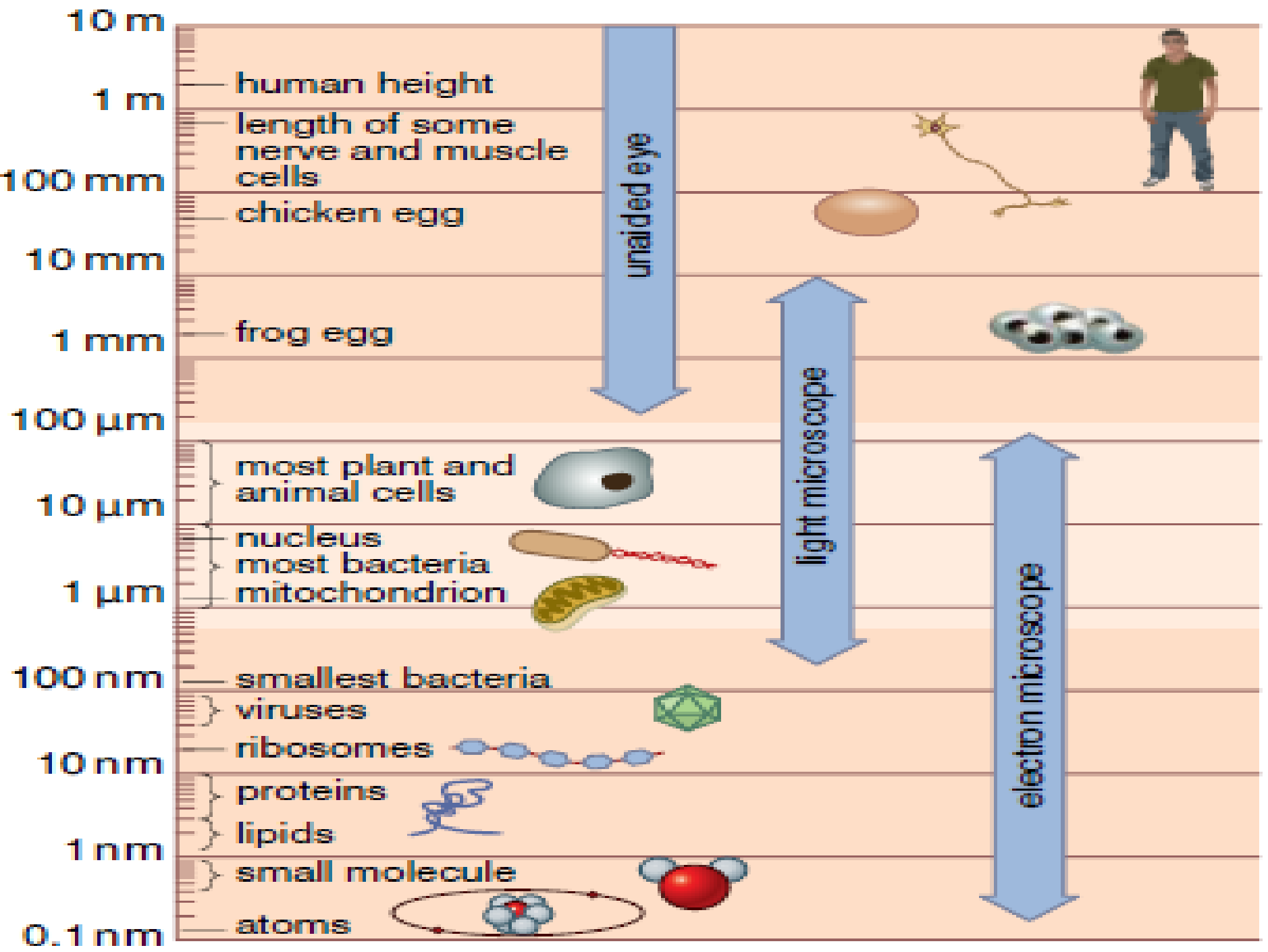
For example, convert 3.5 mm to μm.

$3.5 \text{ mm} = 3.5 \times 1000 = 3500 \text{ μm}$

To convert a smaller unit to the next larger unit, divide by 1000:

For example, convert 87 nm to μm.

$87 \div 1000 = 0.087 \text{ μm}$


10 m
1 m
100 mm
10 mm
1 mm
100 µm
10 µm
1 µm
100 nm
10 nm
1 nm
0.1 nm
human height
length of some nerve and muscle cells
chicken egg
frog egg
most plant and animal cells
nucleus
most bacteria
mitochondrion
smallest bacteria
viruses
ribosomes
proteins
lipids
small molecule
atoms
unaided eye
light microscope
electron microscope

- **Calibrating** correlate the readings of an instrument with a standard.
- To do this properly, you need to use two measuring devices with your microscope:

1. **a stage micrometer** – this is really a microscope slide with a very precise scale etched onto it, and
2. **an eyepiece graticule** – this is a piece of plastic with a less accurate scale than the graticule that fits inside the eyepiece of the microscope.

- The smallest divisions on the stage micrometer slide are 100 μm.
- So each large division on the stage micrometer is 10 times that – 1 mm.

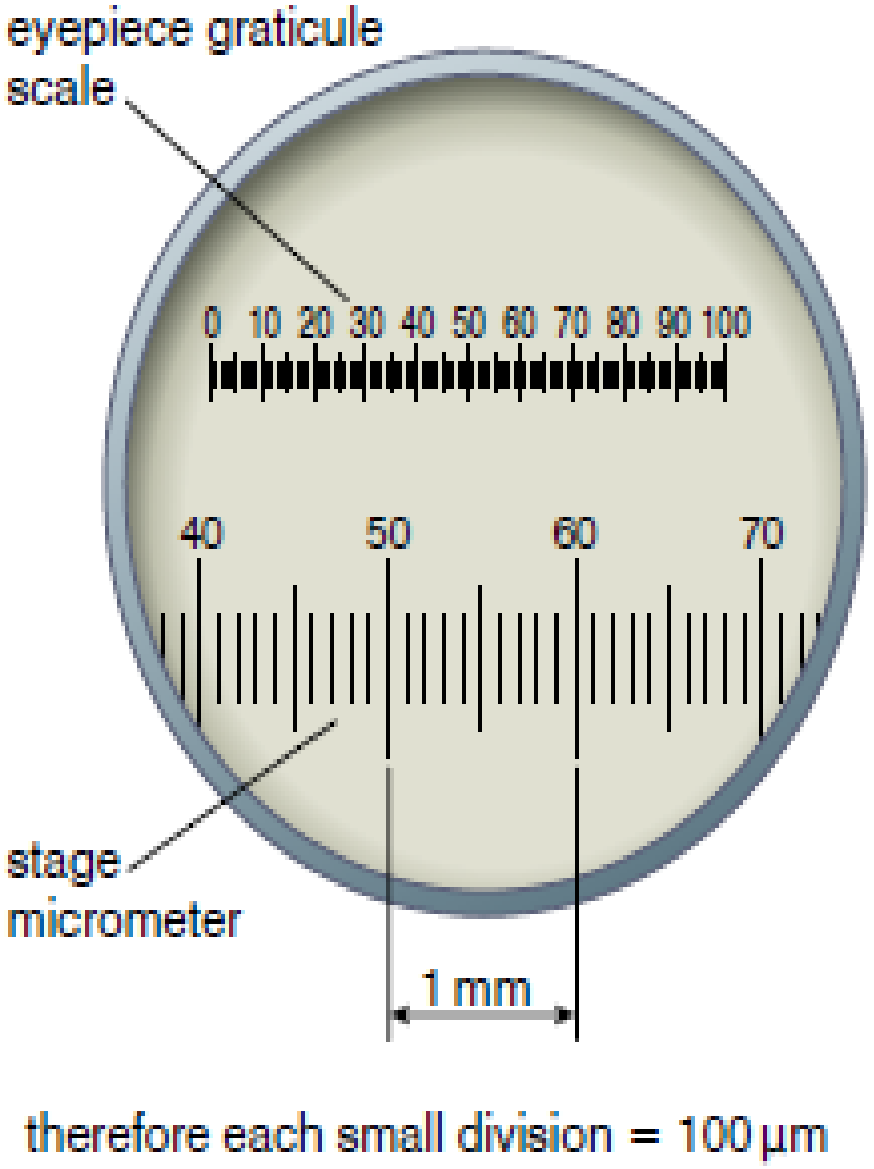



*Figure 4.11 An eyepiece graticule and stage micrometer*

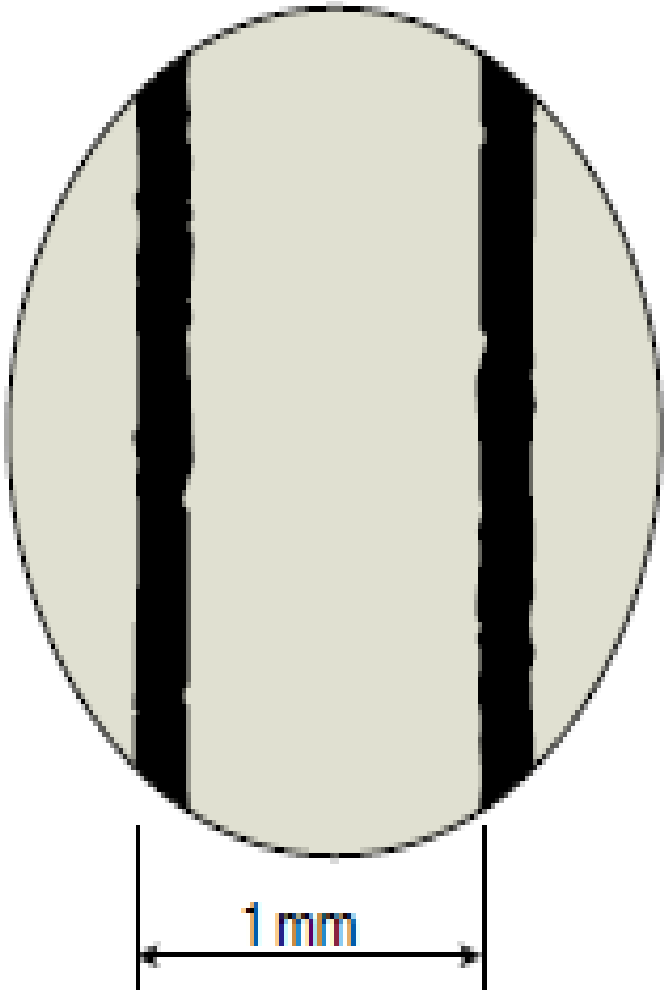



*Figure 4.12 Estimating the field of view*

# What are prokaryotic and eukaryotic cells?

- Prokaryotic cells were the first type of cells to be formed when life first evolved.
- Prokaryotic cells are much smaller and simpler than eukaryotic cells; even so these cells must carry out all the same functions that a eukaryotic cell carries out in order to survive.
- There is therefore some division of labour within the cell.
- There are specialised regions for certain functions.

- However, there is much more division of labour in a eukaryotic cell.

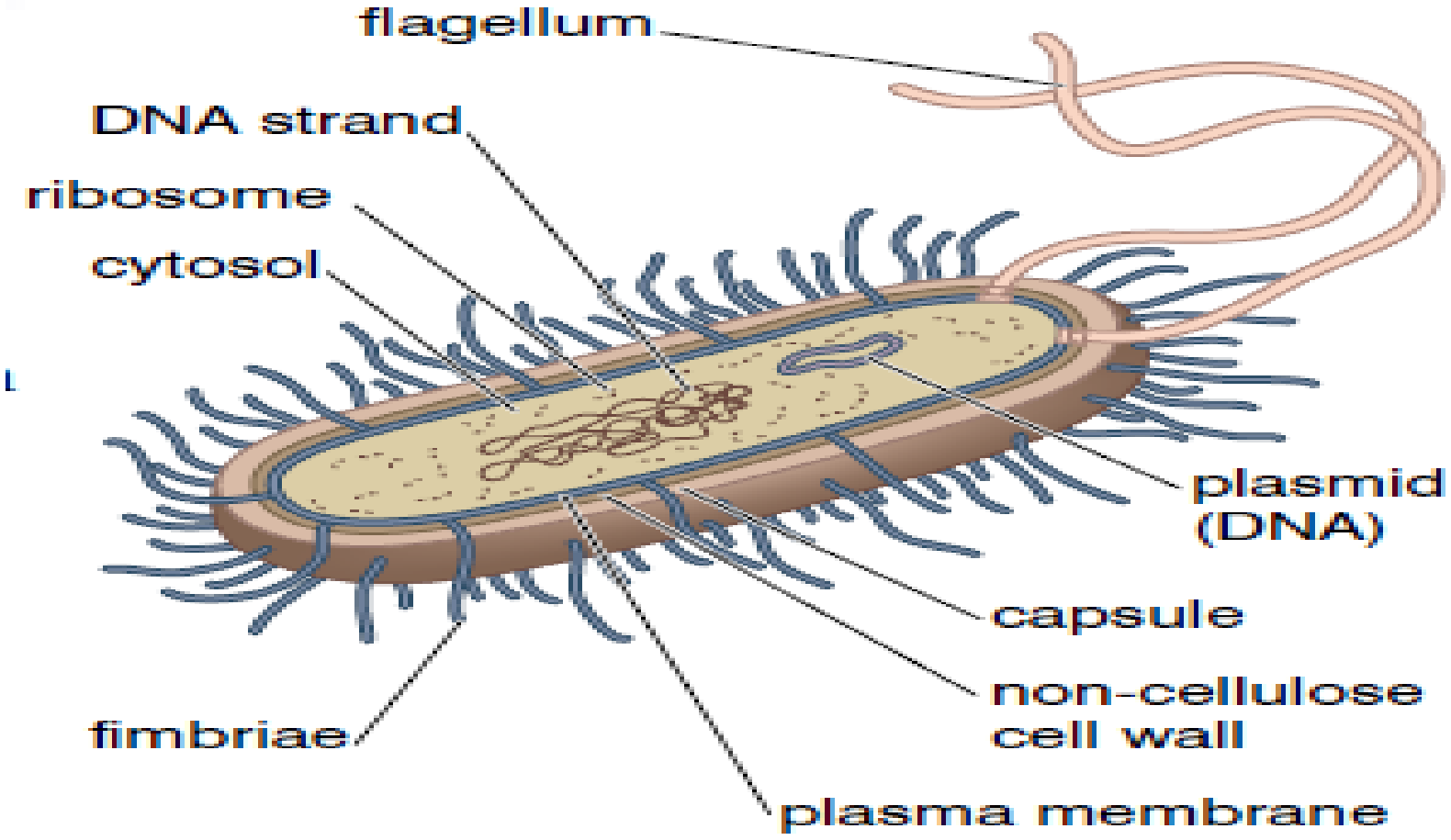



*Figure 4.14 A generalised prokaryotic cell*

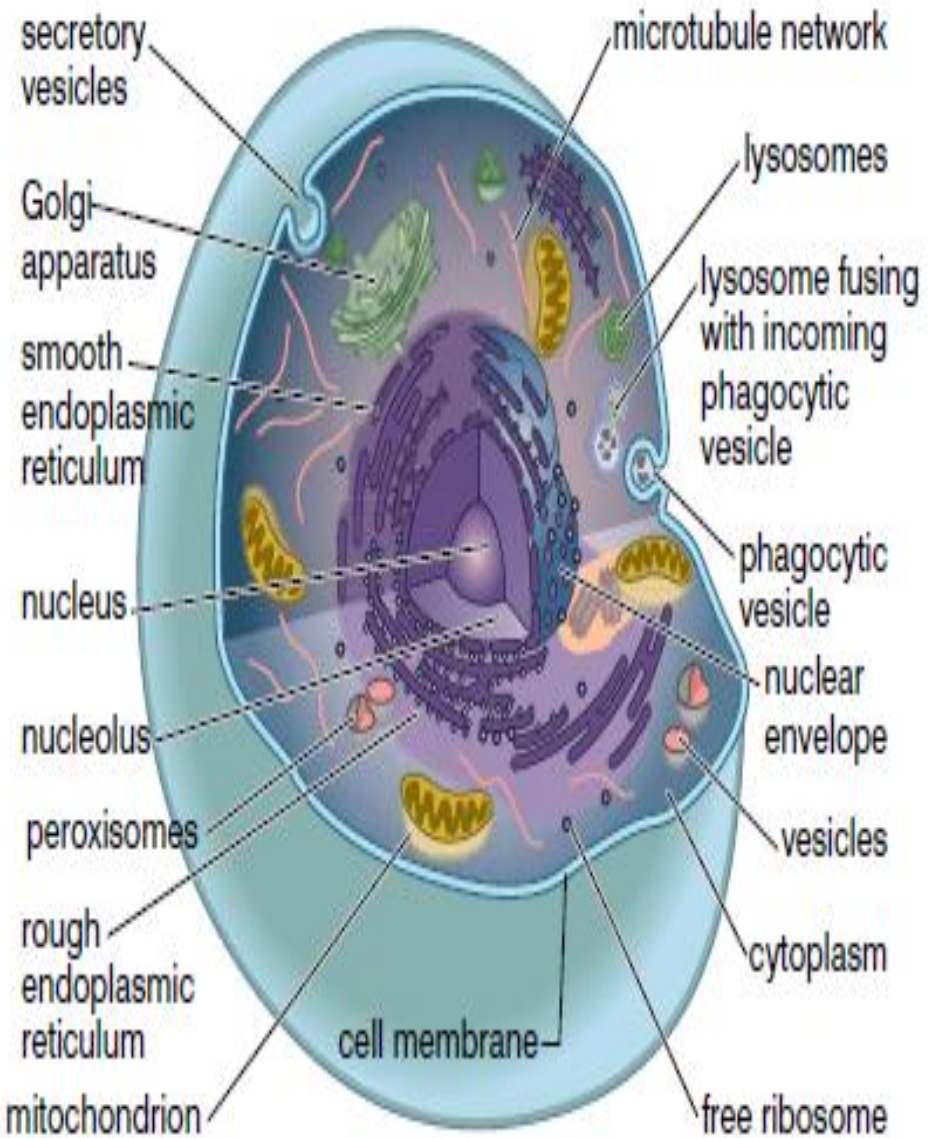



*Figure 4.15 A generalised animal cell*

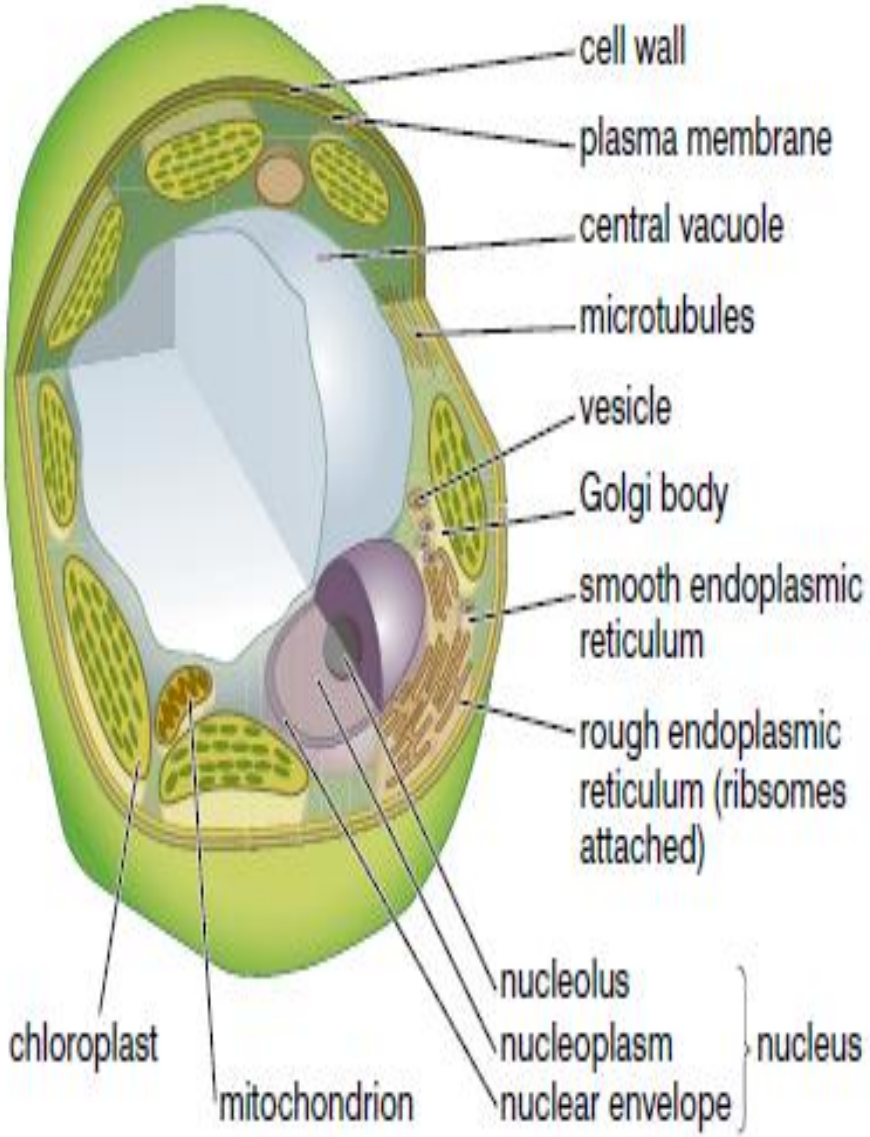



*Figure 4.16 A generalised plant cell*

- There are many more different individual structures, called **organelles**, in the cell.
- Also, there are many more membranes in the cell.
- Some of these form the complex membrane system that is found throughout the cell- the endoplasmic reticulum.
- In addition to these, several of the organelles are surrounded by membranes.
- These are the:

  *Nucleus *mitochondria *chloroplasts
  *lysosomes *Golgi apparatus
- These are called *membrane-bound organelles.*

# Differences between prokaryotic and eukaryotic cells

| Feature | Prokaryotic cells | Eukaryotic cells |
|---|---|---|
| Size | 1–10 µm | 10–100 µm |
| Nucleus | No membrane-bound nucleus | Nucleus surrounded by nuclear envelope |
| DNA | • In a continuous loop<br>• Not associated with protein to form chromosomes | • Linear DNA<br>• Associated with histone proteins in chromosomes |
| Mitochondria | Absent | Present |
| Chloroplasts | Absent (but some prokaryotic cells contain a kind of chlorophyll and can photosynthesise) | Present in some cells (some plant cells and some algal cells) |
| Ribosomes | Present, but smaller than in eukaryotic cells (**70S**) | Present, but larger than in prokaryotic cells (**80S**) |
| Cell wall | • Always present<br>• Not made from cellulose (often made from peptidoglycan) | • Present in plant cells, algal cells and fungal cells<br>• Cellulose in plant cells, various materials in other cells |

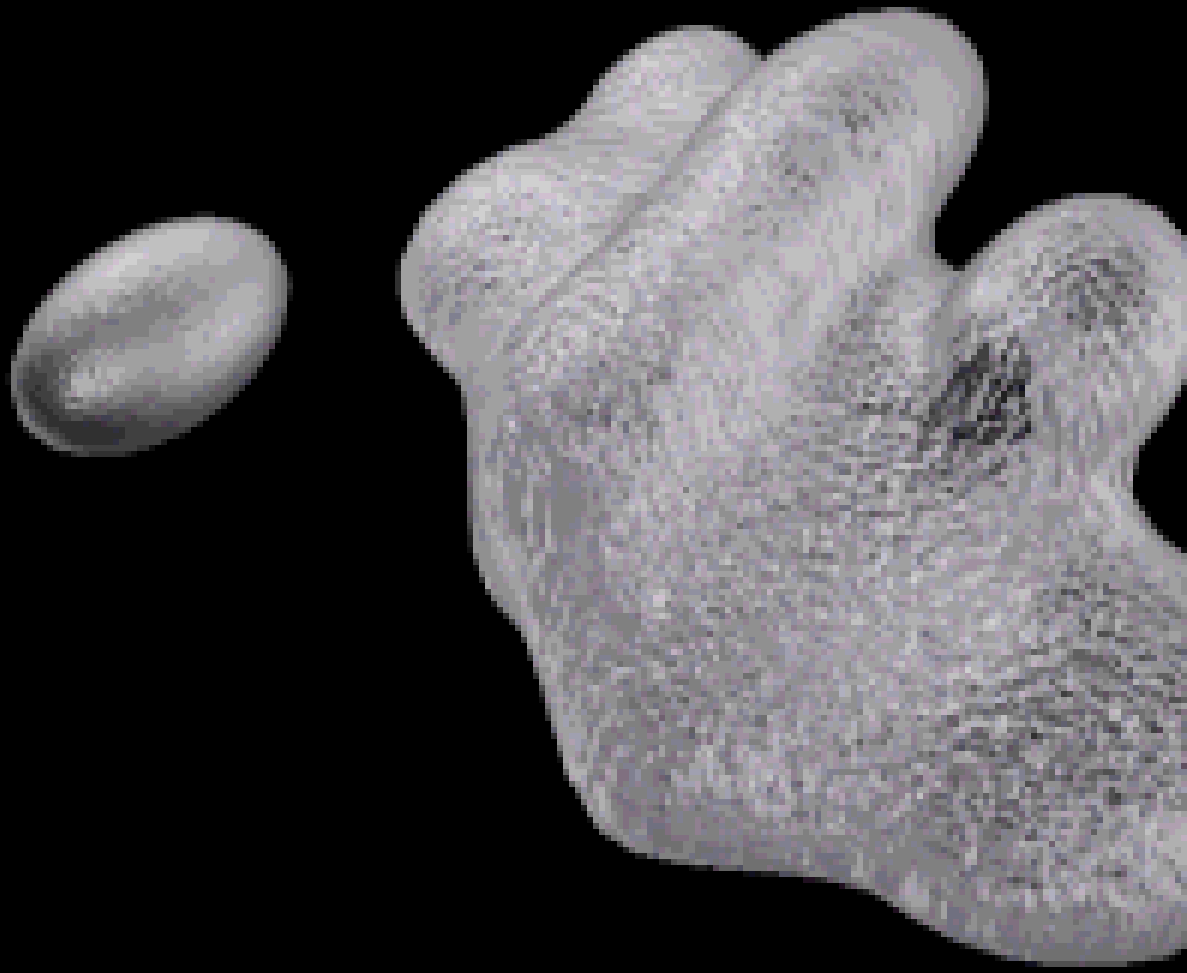
# Parts of the cell and their functions

## 1.The importance of the cell membrane

- The membrane that surrounds and encloses a cell is sometimes called the **cell surface membrane**, but most biologists now refer to it as the **plasma membrane**.
- Although this membrane has little mechanical strength to support the cell, it plays a crucial role in:

1. controlling what enters and leaves the cell; the plasma membrane moves substances in and out of the cell by:

a. simple diffusion
b. facilitated diffusion
c. Osmosis
d. active transport
e. Endocytosis
f. exocytosis



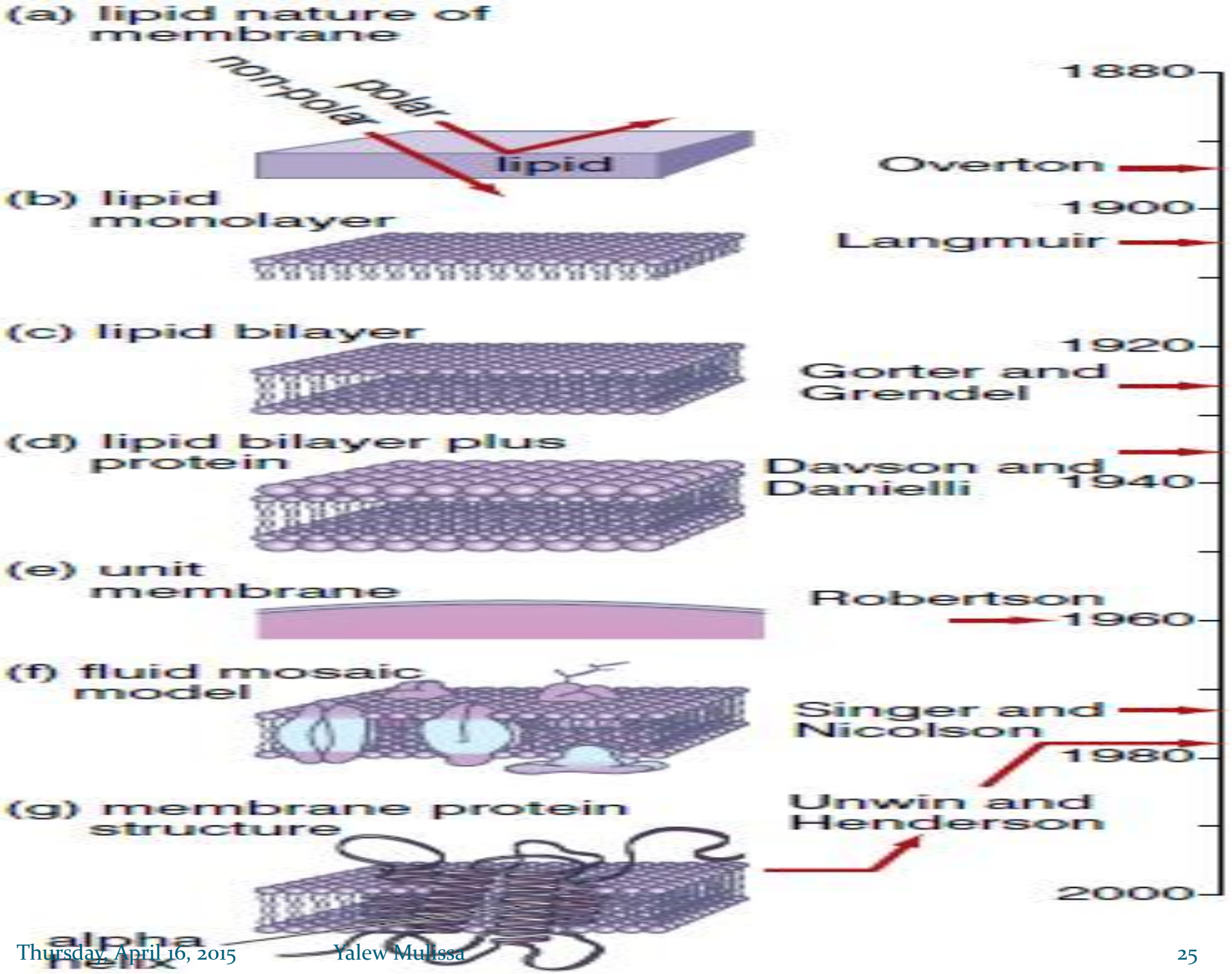
2. cell signalling; various molecules in the membrane allow the cell to be recognised by hormones and the immune system (in animals) and (in plants) growth regulator substances, such as auxins.

- The plasma membrane clearly has a vital role in isolating the cell from its environment, whilst allowing necessary exchanges with that environment.

# What is the plasma membrane like?

- The basis of plasma membranes is a phospholipid bilayer.
- But a plasma membrane is much more complex than a simple bilayer.
- There have been several models of the structure of the plasma membrane.
- The following chart shows some key events in developing the current model of membrane structure.

| Year | Event |
|---|---|
| 1665 | Robert Hooke discovers cells, but only sees dead cells and has no idea of a cell membrane. |
| 1895 | Charles Overton shows that the cell membrane is composed of some kind of lipids. |
| 1905 | Langmuir proposes a lipid monolayer as the basic membrane structure. |
| 1910–1920 | Evidence accumulates to show that the lipid in the membrane must be a phospholipid. |
| 1925 | E Gorter and G Grendel suggest that the plasma membrane is a phospholipid bilayer. |
| 1935 | Davson and Danielli know that proteins are also found in plasma membranes and suggest a 'sandwich' model. |
| 1959 | Based on electron microscope evidence that appears to support the Davson–Danielli model, J D Robertson proposes the unit membrane model – he suggests that all membranes are essentially the same. |
| 1972 | S J Singer and G L Nicholson propose the fluid mosaic model of membrane structure. As more and more supporting evidence accumulates, this is essentially the model we accept today. |


(a) lipid nature of membrane
nonpolar
polar
lipid
(b) lipid monolayer
(c) lipid bilayer
(d) lipid bilayer plus protein
(e) unit membrane
(f) fluid mosaic model
(g) membrane protein structure
alpha helix
1880
Overton
1900
Langmuir
1920
Gorter and Grendel
Davson and Danielli
1940
Robertson
1960
Singer and Nicolson
1980
Unwin and Henderson
2000

# A. The Davson-Danielli model

- In 1935, Davson and Danielli knew that both proteins and phospholipids were involved in the structure of plasma membranes.
- Without any direct observational evidence to assist them Davson and Danielli suggested a kind of 'sandwich' of protein and phospholipid.
- This was based on what they knew of the proportions of the two substances in the membrane.
- The protein was to form the 'bread' of the sandwich with the phospholipid forming the 'filling'.

- In 1954 they proposed a revised model in which they included protein-lined pores.

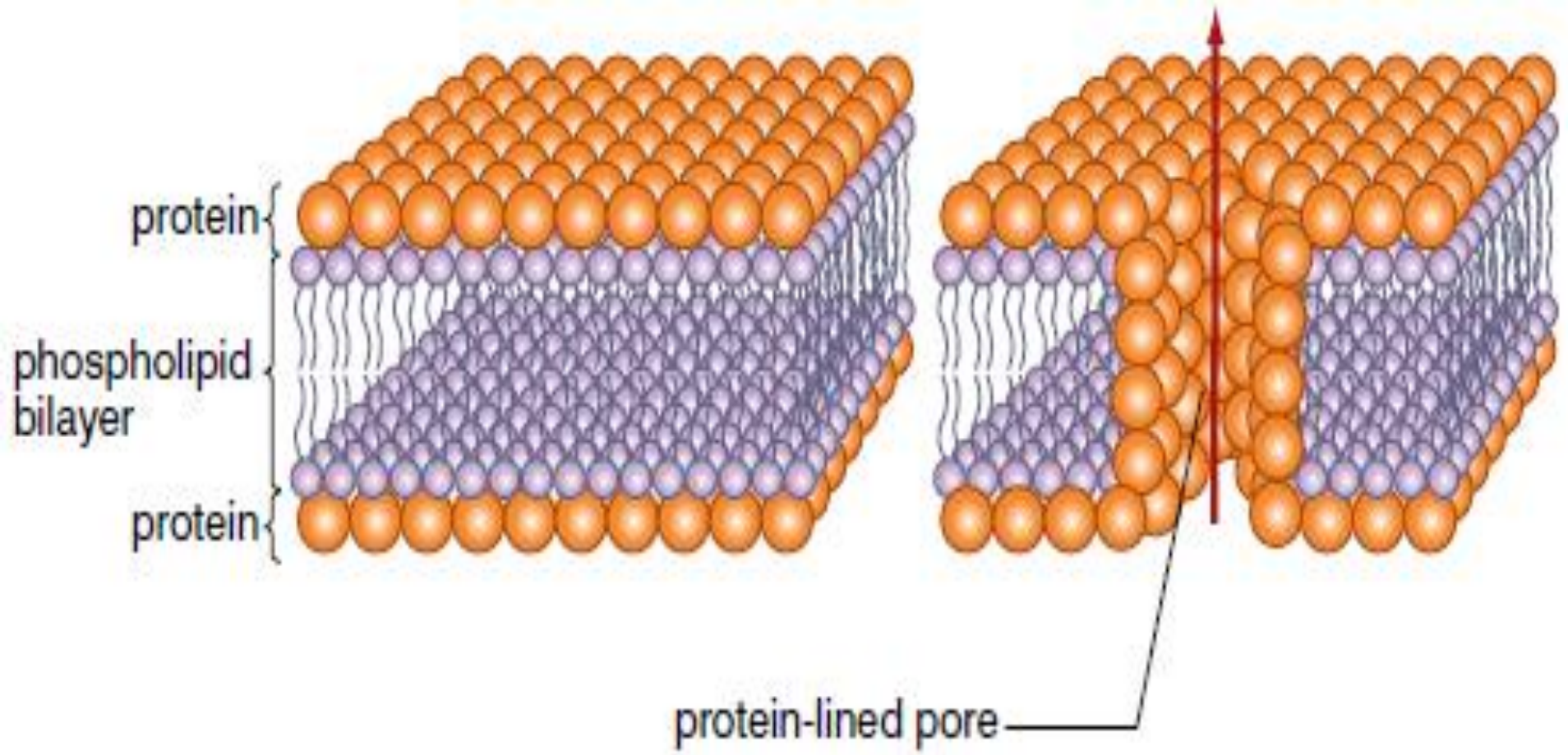
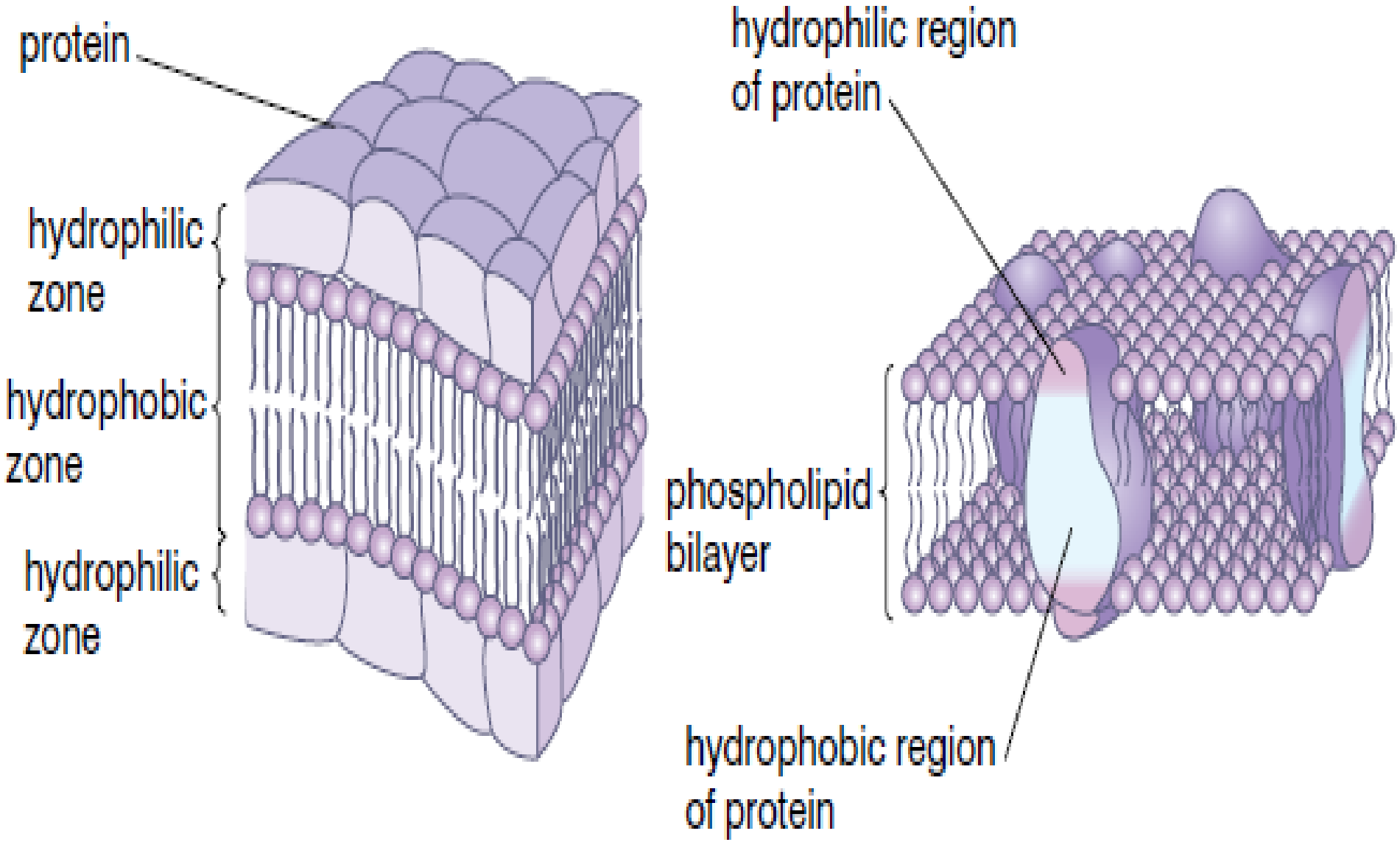



*Figure 4.20 The Davson–Danielli models of 1935 and 1954*

- As more and more evidence accumulated about how molecules moved across membranes, it became clear that the Davson-Danielli model could not adequately explain all the new evidence. The model therefore had to be rejected.

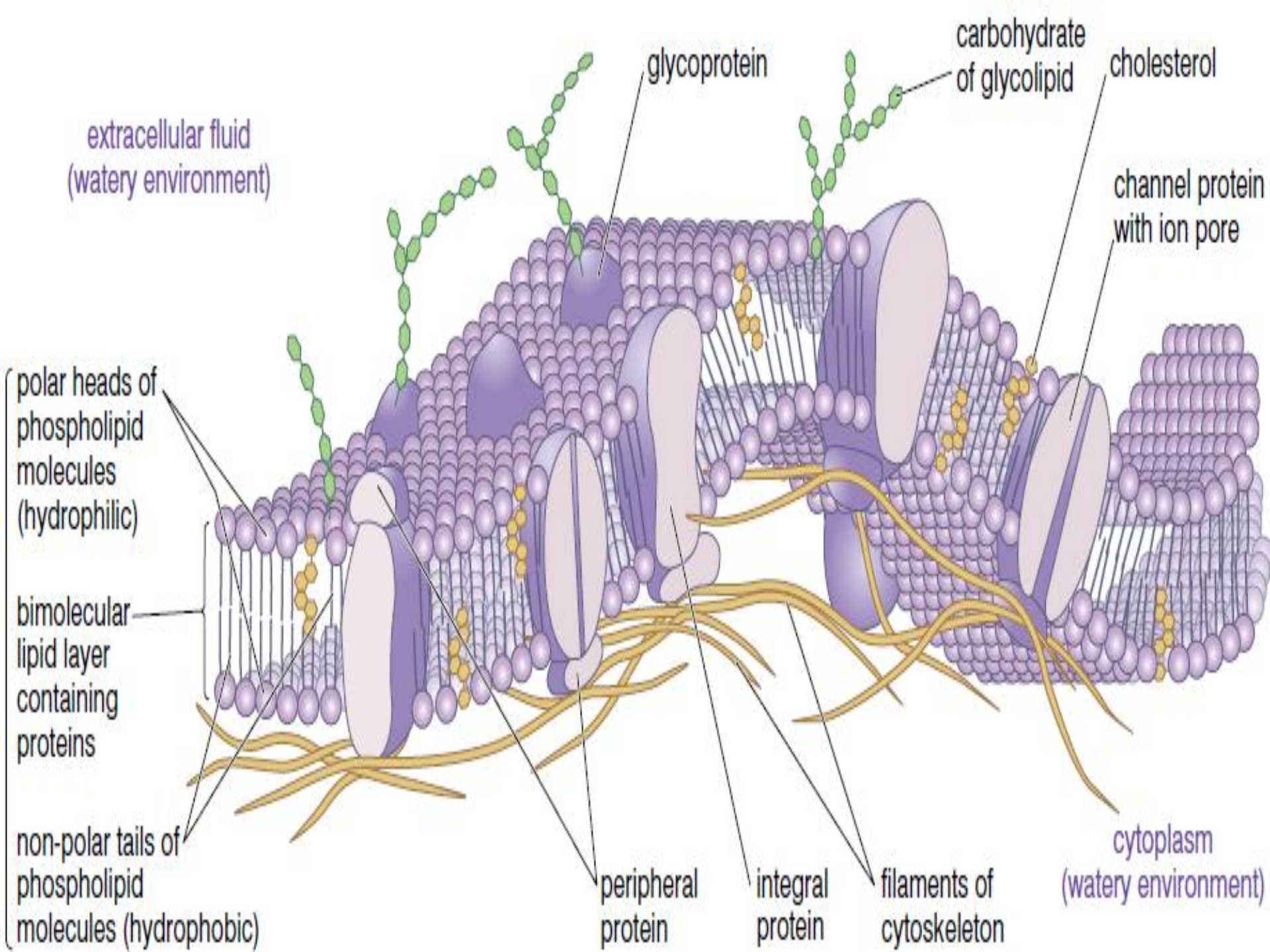
- In 1972, Singer and Nicholson proposed a totally different arrangement of the phospholipids and proteins in the plasma membrane.
- They retained the idea of a phospholipid bilayer, but rejected the sandwich arrangement.
- Instead, they suggested that proteins were 'studded' into the bilayer at different points.
- They also suggested that the arrangement was not static, but was fluid and constantly changing.
- The following is the difference between the Davson-Danielli model and the original fluid mosaic model






A the Davson-Danielli model

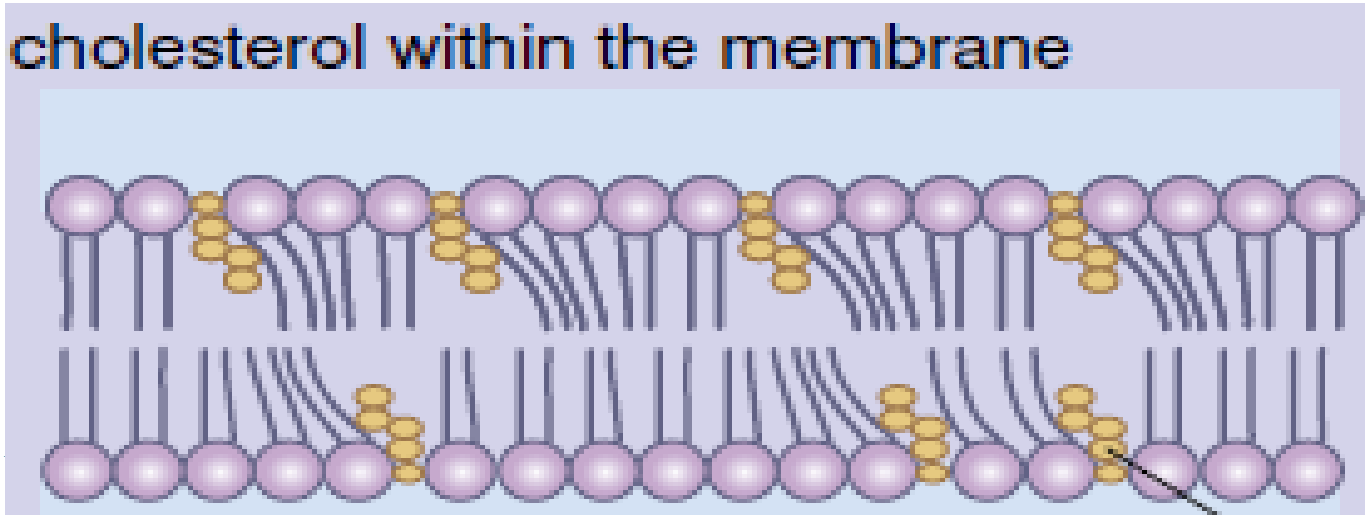
B the current fluid mosaic model


extracellular fluid
(watery environment)
glycoprotein
carbohydrate
of glycolipid
cholesterol
channel protein
with ion pore
polar heads of
phospholipid
molecules
(hydrophilic)
bimolecular
lipid layer
containing
proteins
non-polar tails of
phospholipid
molecules (hydrophobic)
peripheral
protein
integral
protein
filaments of
cytoskeleton
cytoplasm
(watery environment)

- The key features of the model as we currently understand it are:
- The phospholipid bilayer as the basis for the membrane
- **Integral proteins** (also known as intrinsic proteins and trans-membrane proteins) that span the membrane.
- Some of these proteins play an important role in moving substances across the membrane.
- There are three main types of these transport proteins:

1. **Channel proteins** - these proteins have a channel through them along which a specific ion can pass; there are different channel proteins for different ion
2. **Carrier proteins** - these proteins act in a more sophisticated way to move larger molecules through the membrane by facilitated diffusion or active transport; the ones involved in active transport are often referred to as pumps
3. **Peripheral proteins** (also known as extrinsic proteins) that span only one layer (or sometimes less) of the membrane. They have a range of functions; some are enzymes, others anchor integral proteins to the cytoskeleton

- **Glycoproteins** and **glycolipids** - protein and lipid molecules that have carbohydrate chains attached to them and often serve as signals to other cells.
- They also act as receptor sites for hormones and drugs. The carbohydrate component of each can be cell-specific and so allow identification of the cell by the immune system.
- **Cholesterol** - reduces the fluidity of the membrane.

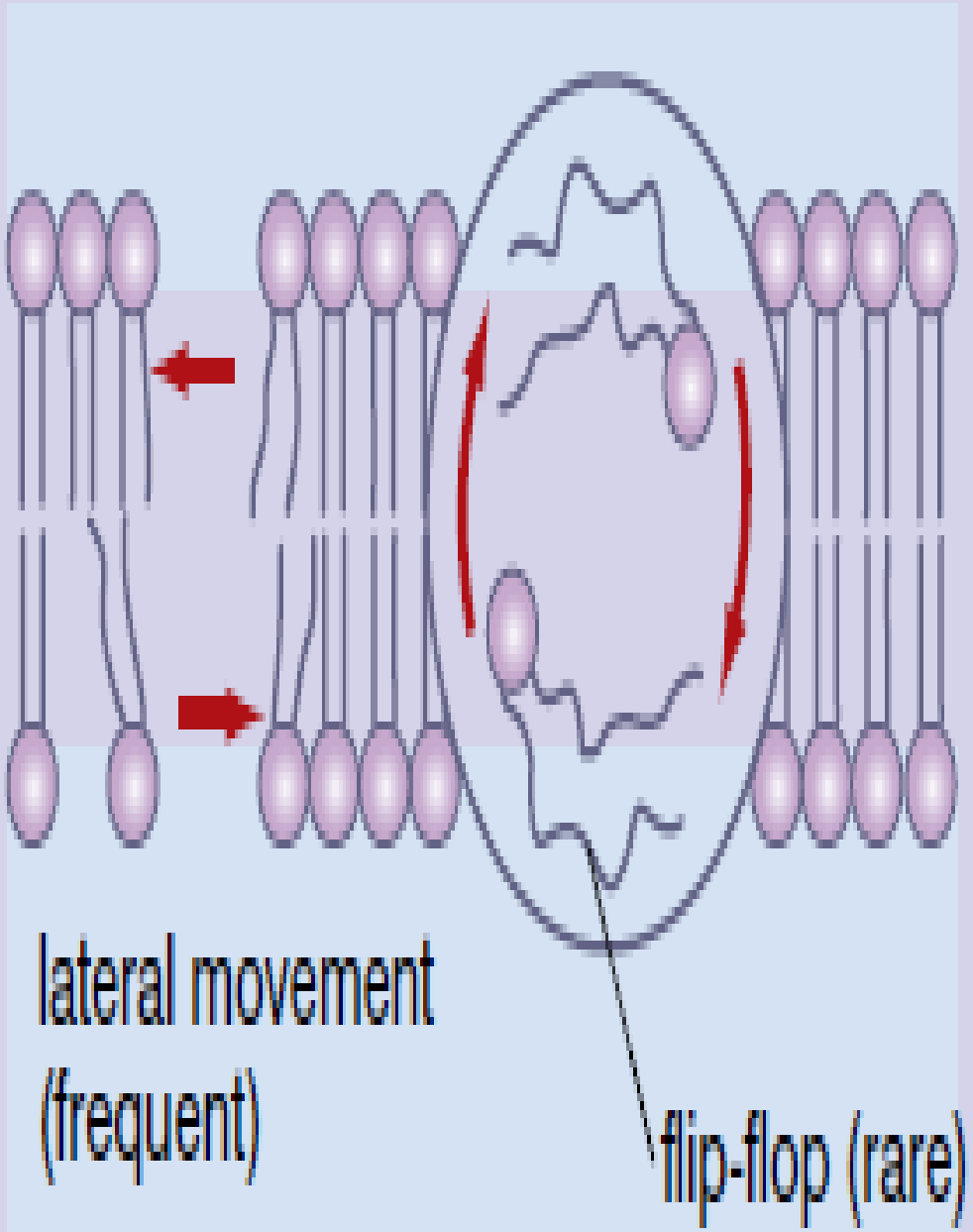


- ***integral proteins*** proteins that span both phospholipid layers in a plasma membrane
- ***channel proteins*** integral proteins with pores that allow ions to pass through the membrane
- ***carrier proteins*** integral proteins that move medium-sized particles across the membrane

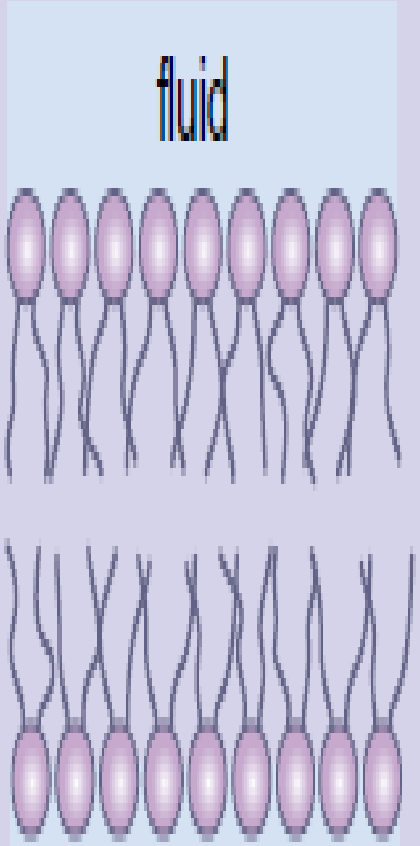
# Why is the fluid mosaic model called the fluid mosaic model?

- It is fluid mainly because the phospholipids in the membrane can move and change position.
- The **nature of the fatty acids** (saturated or unsaturated) and the **amount of cholesterol** in the membrane both influence the fluidity of the membrane.
- The 'mosaic' part of the name comes from the way the proteins in the membrane give a patchwork appearance when viewed from the inside or outside.
- This is rather like a mosaic.

## movement of phospholipids

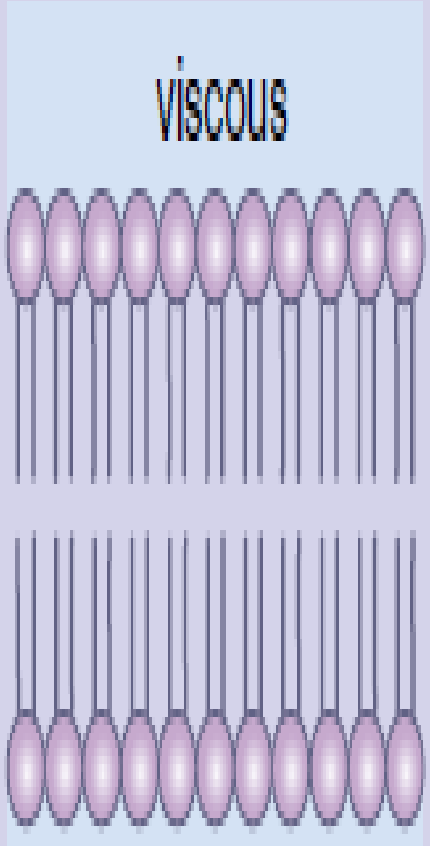



## membrane fluidity



fluid

unsaturated hydrocarbon tails with kinks



viscous

saturated hydrocarbon tails

# How do substances cross the plasma membrane?

- Not all particles can actually pass through a plasma membrane unaided.
- This is because of the largely lipid nature of the membrane.
- To pass through the plasma membrane by simple diffusion particles must be:

a) Small
b) lipid soluble
c) non-charged

- This excludes particles such as ions (they are charged), sugars and amino acids (they are not lipid soluble and are not small particles) and any of the really large particles, such as proteins
- We can group the processes by which substances cross plasma membranes into two main types:

a. **passive processes** - these processes rely only on the kinetic energy of the particles of the substances and on concentration gradients; they need no extra energy from the cell's metabolism
b. **active processes**- these require energy from the cell's metabolism in the form of ATP to drive the transport

# Passive processes

## 1. Simple diffusion

- In fluids - liquids and gases - the particles that make up the fluid are free to move around.
- This kinetic energy is what drives diffusion.
- If particles are, for some reason, concentrated in a small area, they will move in such a way that the particles 'spread out' and occupy all the space that is available to them.
- This is a result of random particular motion. Diffusion need not involve a membrane

- When particles diffuse across a plasma membrane, there must be a concentration difference between the two sides of the membrane (a concentration gradient) to drive the process.
- As diffusion proceeds, the high concentration will decrease and the low concentration will increase until the two concentrations are the same.
- At this point there will be no further net diffusion.
- This means that although particles will still move across the membrane, they will move equally in both directions, so there will be no overall effect.
- We say that the concentrations are in equilibrium

*Table 4.4 The transport process*

| Passive processes | | Active processes | |
|---|---|---|---|
| **Process** | **Brief description** | **Process** | **Brief description** |
| Simple diffusion | Particles move from a high concentration to a low concentration. | Active transport | Particles move from a low concentration to a higher concentration using a carrier protein (pump). |
| Facilitated diffusion | Particles move from a high concentration to a low concentration through an ion pore or carrier protein. | Endocytosis | Large particles are engulfed by the plasma membrane invaginating and forming a vesicle. |
| Osmosis | Water molecules move from a high water potential to a lower one. | Exocytosis | Large particles are secreted by a vesicle in the cell merging with the plasma membrane to release the substance. |

# The rate at which diffusion across a membrane takes place is influenced by:

a. The concentration gradient - a bigger difference in concentration results in faster diffusion than a smaller gradient
b. The thickness of the membrane - as all plasma membranes are the same thickness, this is not really an issue when considering diffusion into and out of cells, but for other situations where particles must cross some kind of barrier, a shorter distance results in faster diffusion
c. The surface area of the membrane - clearly if there is more membrane where diffusion can take place, diffusion will happen faster

- These features are all related in an equation called **Fick's law** of diffusion:

$$\text{Rate of diffusion} \propto \frac{\text{Surface area of membrane} \times \text{Concentration difference}}{\text{Diffusion distance}}$$

- The rate of diffusion is also influenced by **temperature**.
- Diffusion occurs faster at higher temperatures because the particles have more kinetic energy and so move faster.

# 2. Facilitated diffusion

- Facilitated diffusion is essentially the same process as diffusion, in that it depends on a concentration gradient to allow particles to cross the membrane.
- However, it differs in that the particles must be helped to diffuse across the membrane (their diffusion must be 'facilitated') by a carrier protein or a channel protein with an ion pore.
- Note that in both cases that the particles are moving from a high concentration to a low concentration as with simple diffusion.

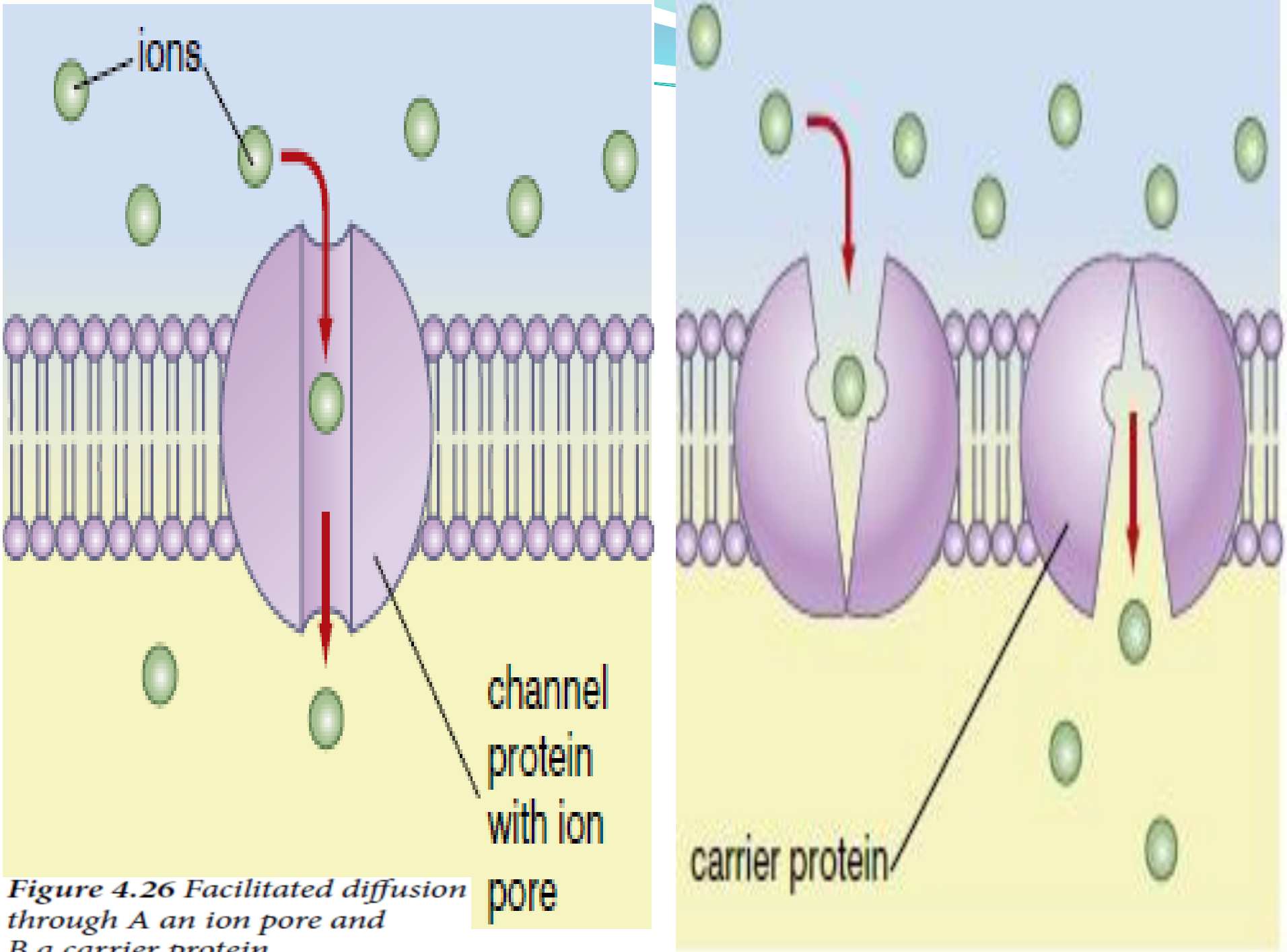



*Figure 4.26 Facilitated diffusion through A an ion pore and B a carrier protein.*

- However, also note that whilst the ions can simply move straight through the ion pore of a channel protein, the carrier protein must undergo a conformational change (change in shape) to move particles through the membrane.
- The rate of facilitated diffusion is affected by the same factors that affect simple diffusion with the exception that it is *not the actual surface area* of the membrane that determines the rate, but the *number of carrier proteins* (or channel proteins) present.

# 3. Osmosis

- Osmosis is the process by which water moves across a partially permeable membrane.
- It is, effectively, the **diffusion of water**.
- However, we do not refer to the concentration of water molecules, but to water potential.
- We can say that osmosis is the movement of water from a system with a high water potential to a system with a low water potential across a partially permeable membrane.

- The symbol for water potential is the Greek letter **Ψ (psi).**
- Water potential is measured in units of pressure - pascals (Pa), kilopascals (kPa) or megapascals (MPa).
- Pure, liquid water has a higher water potential than any other system.
- It is defined as zero

$$\Psi\ (pure\ water) = 0\ Pa$$

- All other systems (cells, solutions and suspensions) have a water potential that is lower than that of water.
- Therefore, their water potential values must be negative.

- So we can define osmosis more accurately as follows:
  - ***Osmosis*** *is the movement of water from a system with a high (less negative) water potential to one with a lower (more negative) water potential, across a partially permeable membrane.*
- The water potential of a system is due to the concentration of free water molecules in that system.
- In pure water, there are only water molecules.
- When a solute is added, some of the water molecules form 'hydration shells' around the solute molecules.

- This reduces the number of (free) water molecules in the system and so the water potential is reduced.
- pure water is assigned a water potential of zero, the solution must have a negative water potential.
- A more concentrated solution will take more free water molecules out of the system and lower the water potential still further, making it more negative.

- The rate at which osmosis proceeds is influenced by the same factors as simple diffusion:

1. surface area of the membrane
2. difference in water potential
3. distance the molecules must travel

- **100% pure water has $\psi = 0$, which is the highest possible water potential, so all solutions have $\psi < 0$, and you cannot get $\psi > 0$.**

# What happens to cells placed in solutions of different concentrations?

- This depends on what type of cell.
- Animal cells have no cell wall, whereas plant cells do and this has a significant influence on the outcome.
- The difference in water potential between cell and solution will determine whether water enters or leaves by osmosis.
- When comparing the water potential of a solution to that of a cell, we could describe it as:

1. **isotonic solution** having the same water potential as the cell.
2. **hypertonic solution** having lower (more negative) water potential than the cell.
3. **hypotonic solution** having a higher(less negative) water potential than the cell.

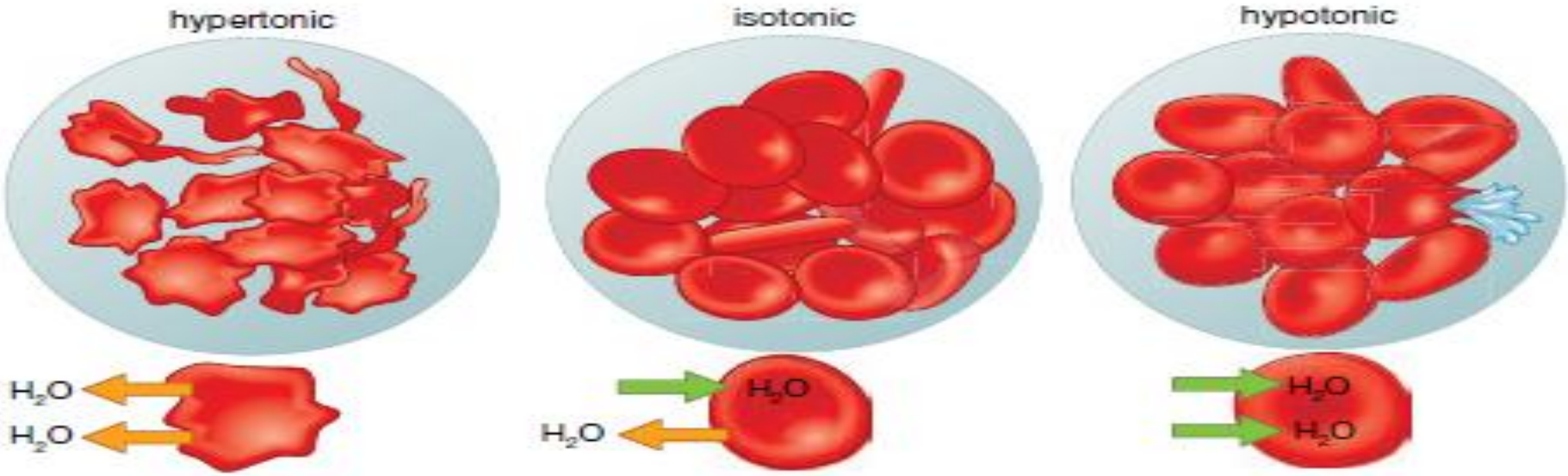
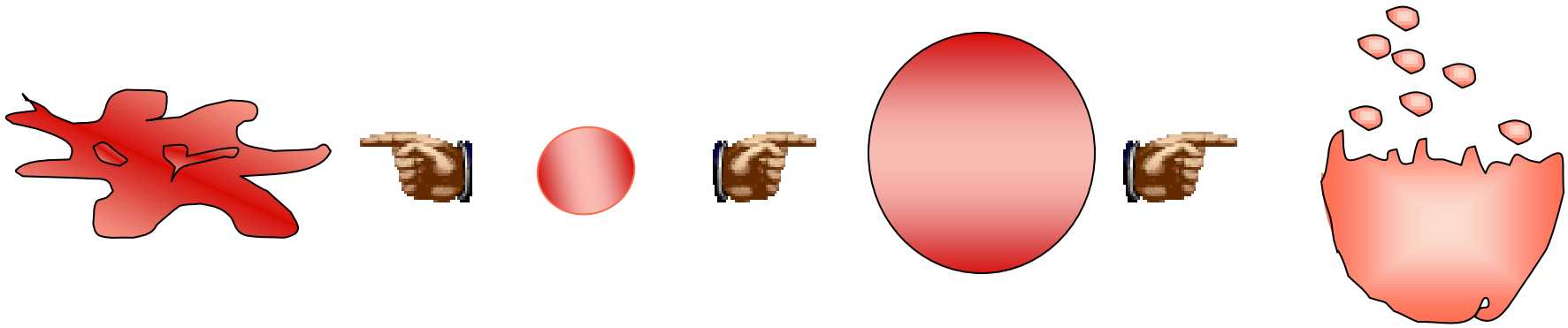



*Figure 4.28 The effect of different solutions on red blood cells*

Hypertonic solution | Isotonic solution | Hypotonic solution | Remains of cell surface membrane



**Crenation**: Red blood cell shrinks and turns 'spiky'

Red blood cell

Swells up

**Haemolysis**: Red blood cell finally burst

CRENATION AND HAEMOLYSIS OF RED BLOOD CELL

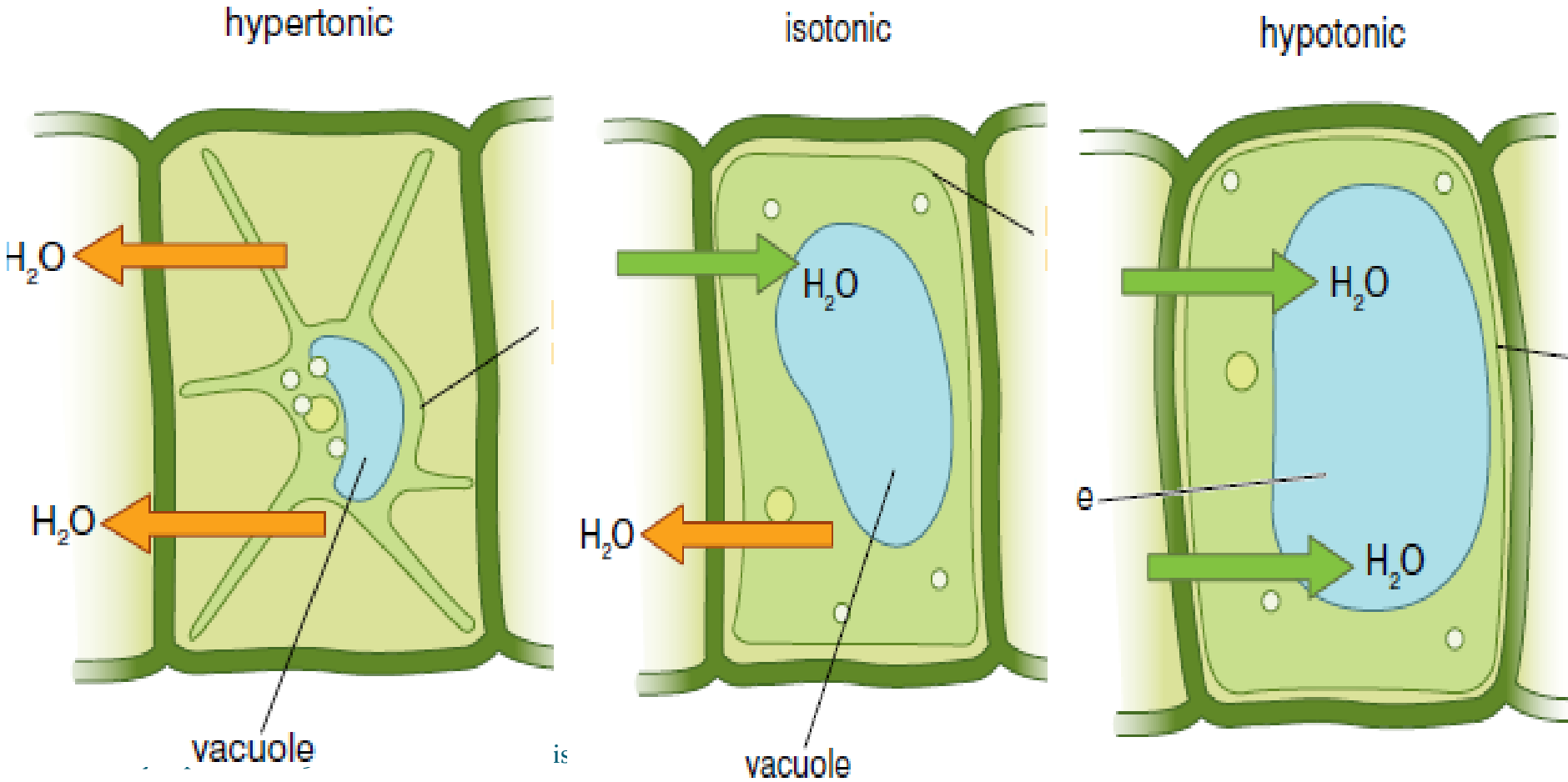
# The effect of different solutions on plant cell

- In the hypertonic solution, the cytoplasm of the cells loses water by osmosis and shrinks.
- Because of this, there is no pressure from the cytoplasm on the cell wall.
- The cell is said to be **flaccid**.
- If the cytoplasm shrinks too much, it loses contact with the cell wall and we say the cell has been plasmolysed.
- In the hypotonic solution, the cells gain water by osmosis and swell.

What are the followings?

1. Turgor pressure
2. Wall pressure

- However, because of the cell wall, the cell cannot become much larger.
- Plant cells in this condition are **turgid**.
- There is no change in the isotonic solution



# Active processes

## 1. Active transport

- Sometimes, substances must be moved against a concentration gradient - from a low concentration to a higher one.
- This cannot happen by diffusion, since it would tend to concentrate particles rather than spread them out.
- It can only happen if metabolic energy is used to drive the process.
- In living organisms, this energy is released from the ATP produced in respiration.

- When the energy is released from ATP, it is broken down into **ADP** and **$P_i$** (inorganic phosphate).
- The proteins used to actively transport substances across plasma membranes are called **Pumps.**

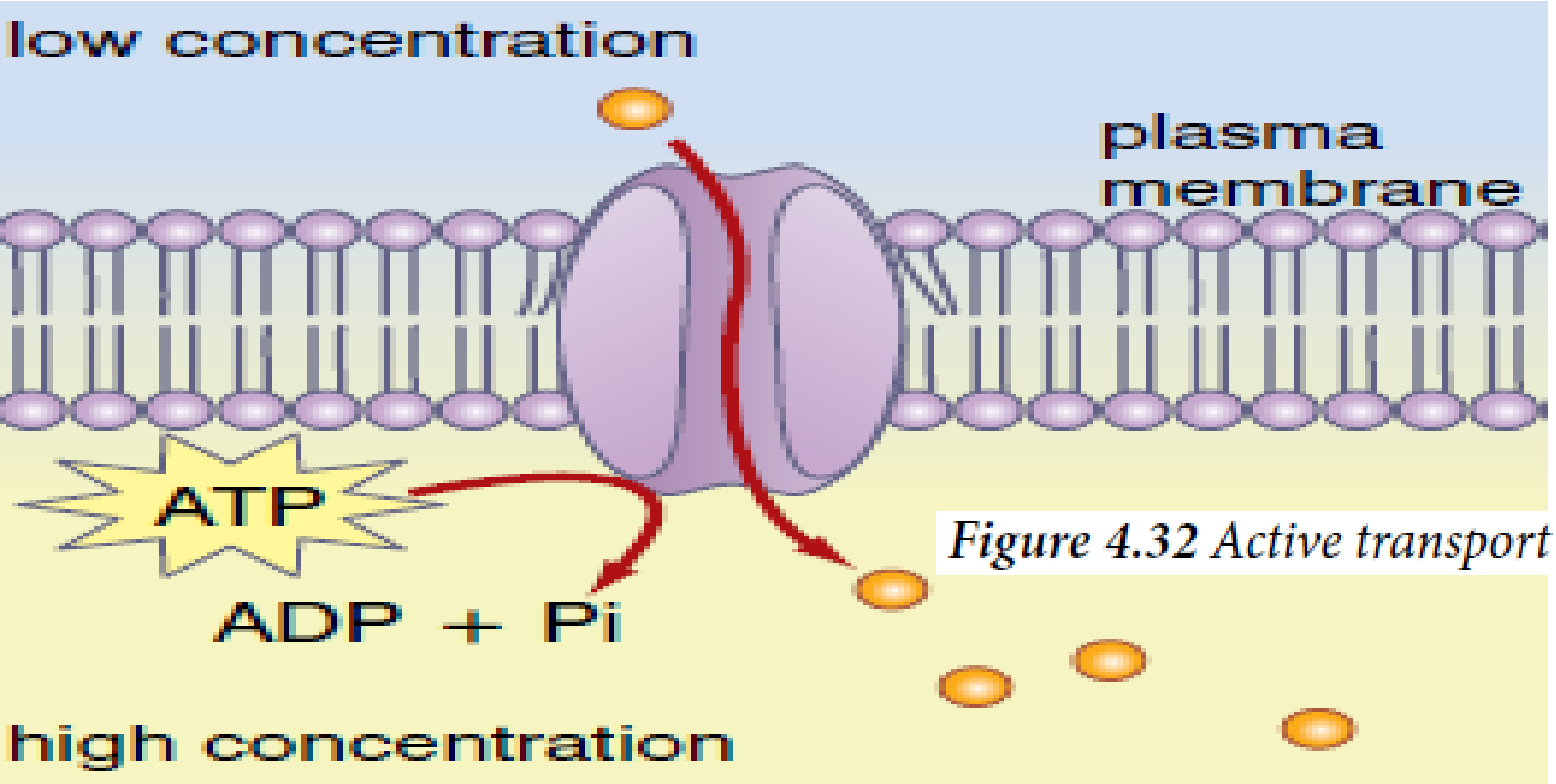
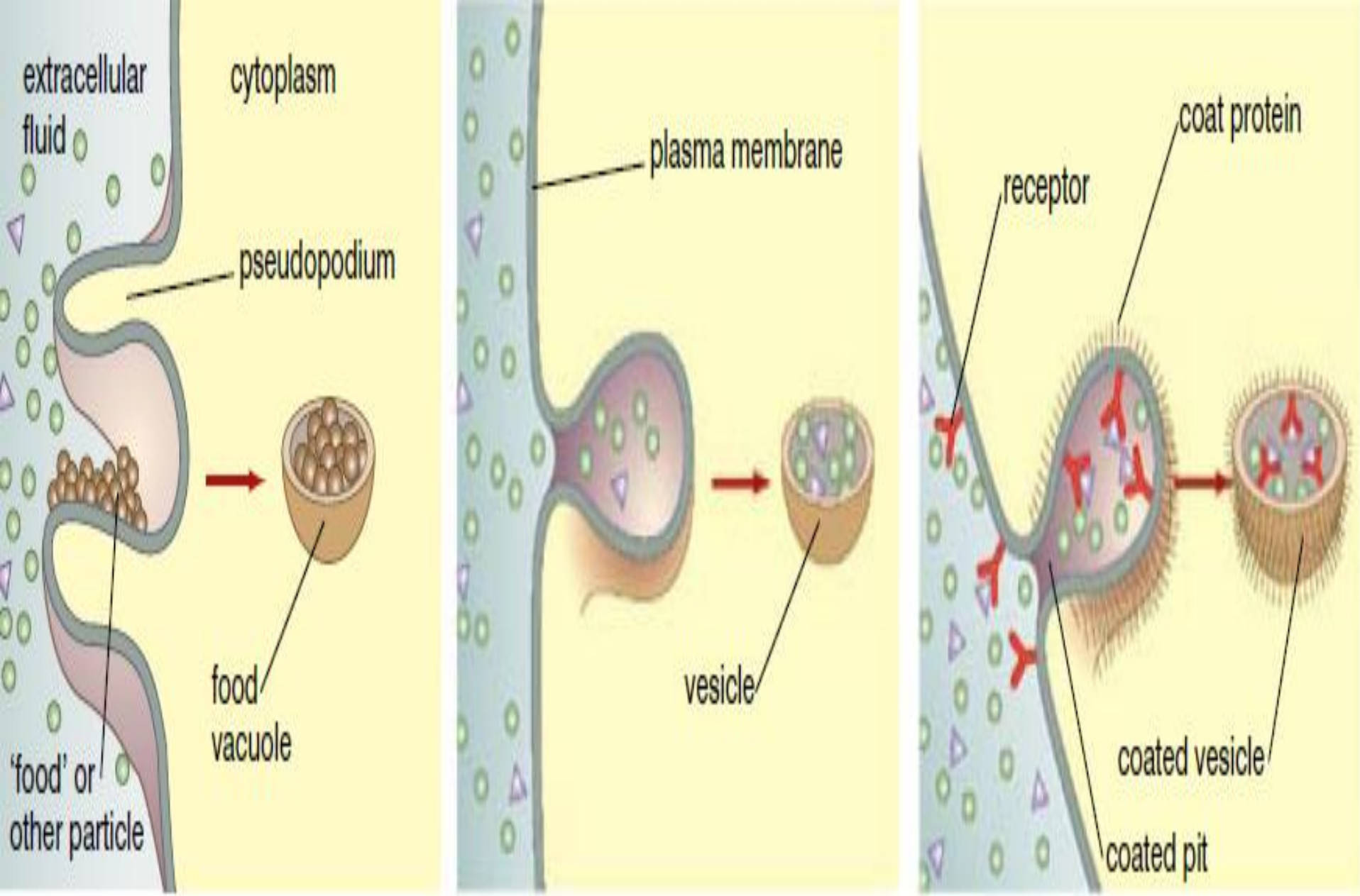



*Figure 4.32 Active transport*

## 2. Endocytosis

- In this process, large particles are engulfed by a cell.
- There are several ways in which it can happen, but, essentially, part of the plasma membrane surrounds the particles to form a vesicle which is then processed by the cell.
- All of them require ATP to move the membrane around the particles to form the vesicle.




A phagocytosis

B pinocytosis

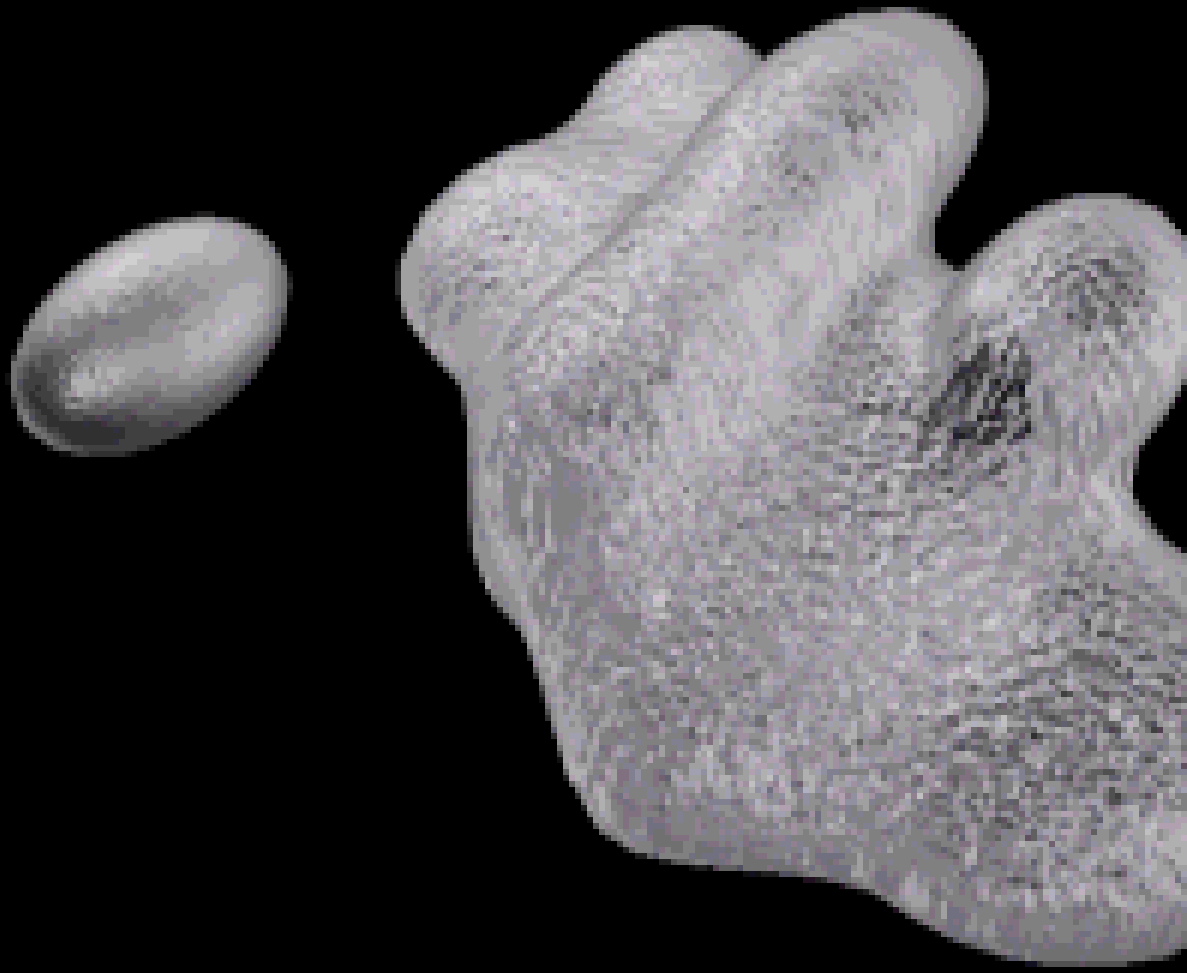
C receptor-mediated endocytosis

## A. Phagocytosis/ cell eating

- This involves the creation of pseudopodia to enclose large particles or even whole organisms outside the cell.
- Once enclosed by the pseudopodia, they form an internal vesicle which is then moved further inside the cell.

## B. Pinocytosis / cell drinking

- This differs from phagocytosis only in scale.
- It involves the ingestion of smaller particles and *does not require* the formation of large pseudopodia to engulf the particles.

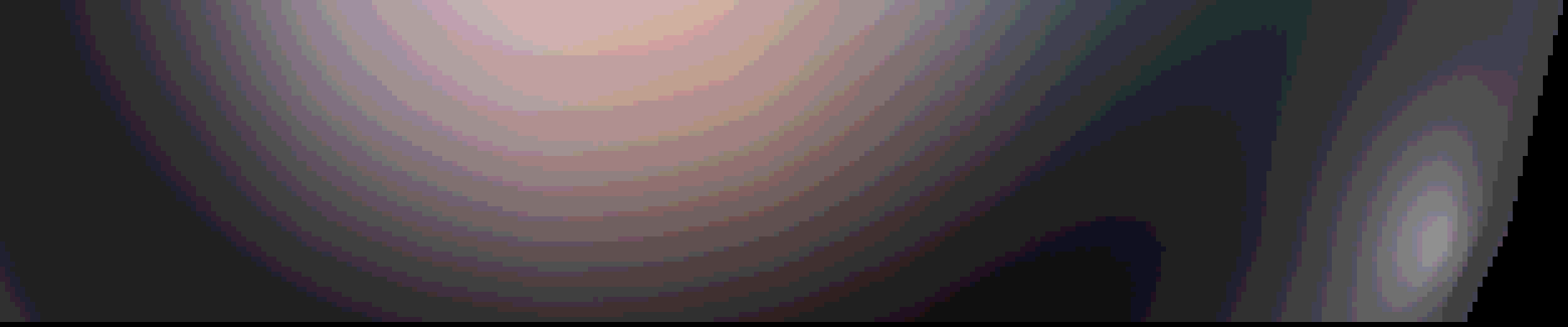


## 5. Receptor-mediated endocytosis

- The membrane infolds to form vesicles only in regions where particles have bound to specific receptors.
- The binding stimulates the infolding.

## 6. Exocytosis

- In this process, substances are moved from the inside to the outside of the cell in what is, effectively, the reverse of *endocytosis.*
- It is the process by which enzymes and hormones are secreted.
- Again, ATP is used to alter the configuration of the membrane.



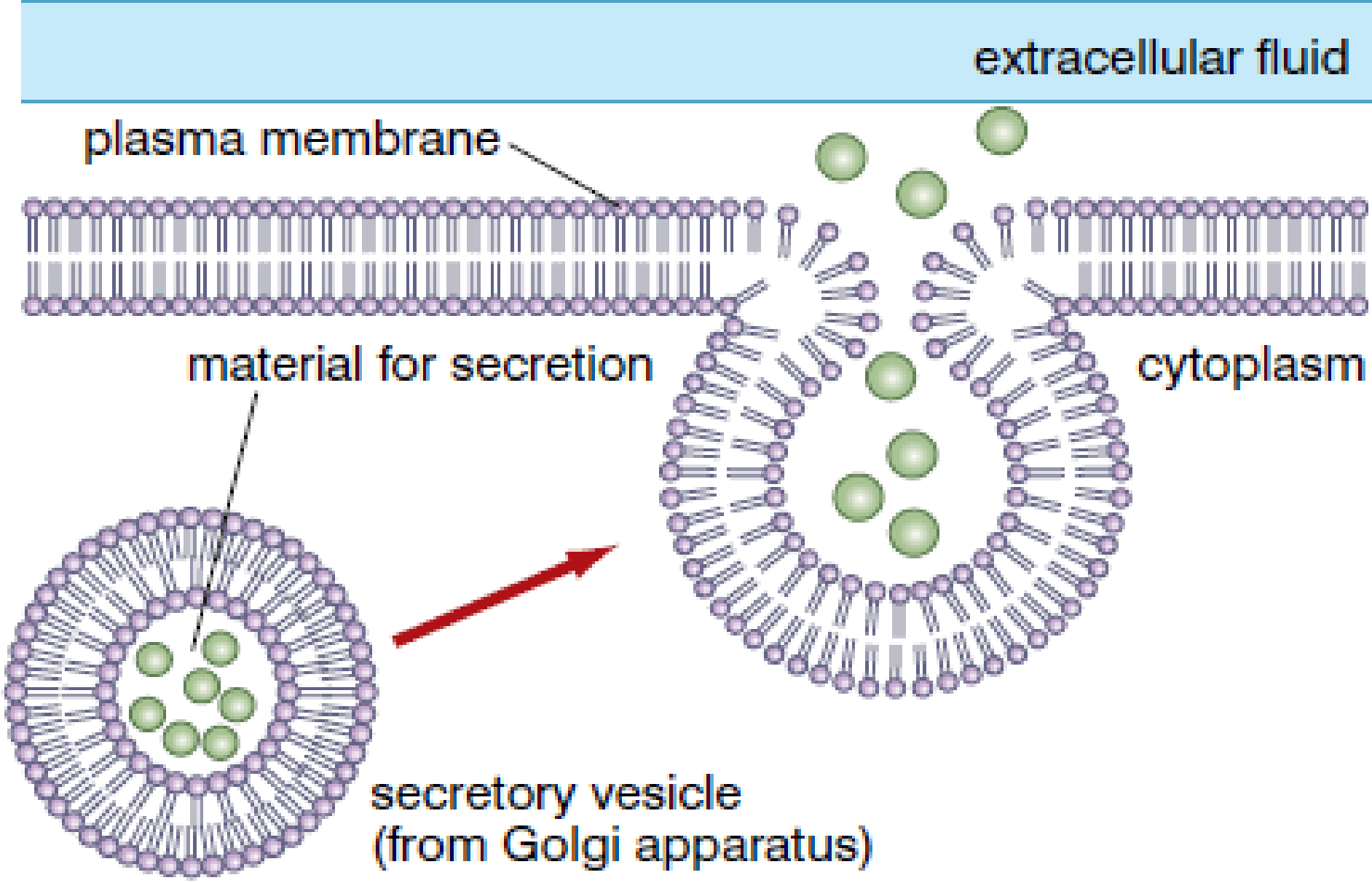



*Figure 4.34 Exocytosis*

# The nucleus

- The nucleus typically occupies about 10% of the volume of a cell. It has several components:

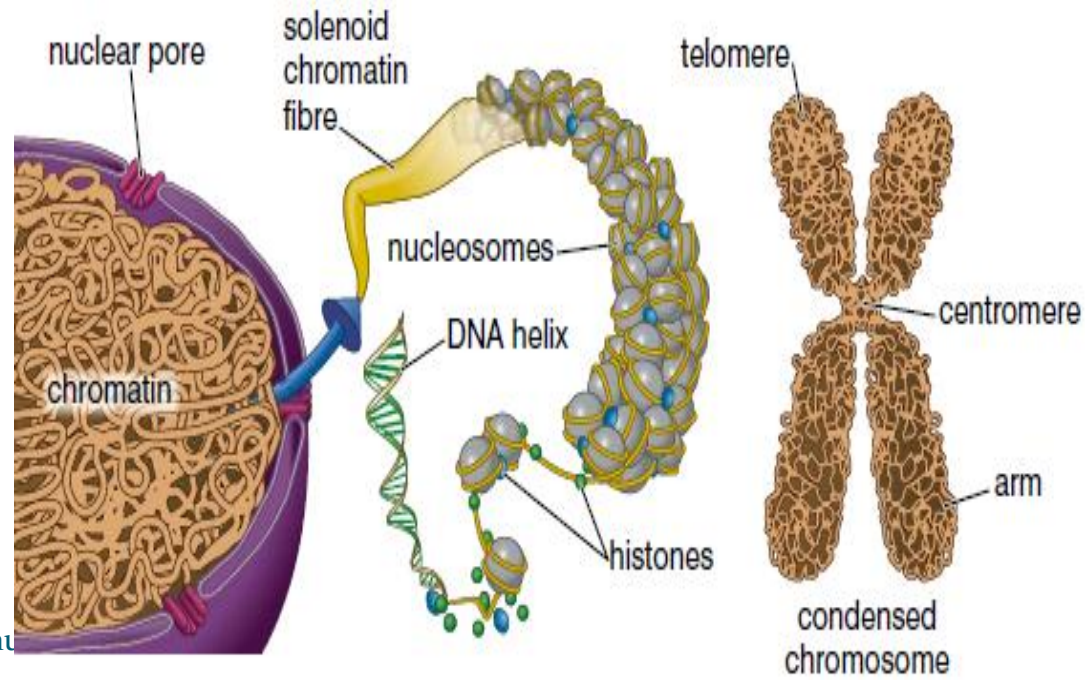
a. **The nuclear envelope** is a double membrane that surrounds the nucleus. There are many nuclear pores, which allow the passage of some molecules between the nucleus and the cytoplasm.

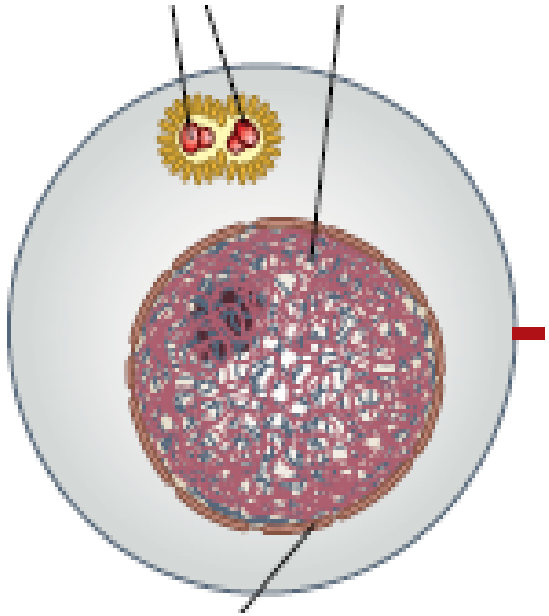
b. **The nucleolus** is an organelle within the nucleus. It is not membrane-bound.

- Its function is to synthesise the components of ribosomes, which then pass through the nuclear pores into the cytoplasm.

**C. Chromatin** consists of DNA molecules bound with proteins called **histones.**

- For most of the cell cycle, the chromatin fibres are loosely dispersed throughout the nucleus.
- Just before a cell is about to divide, the chromatin condenses into distinct, recognisable structures called **chromosomes**.



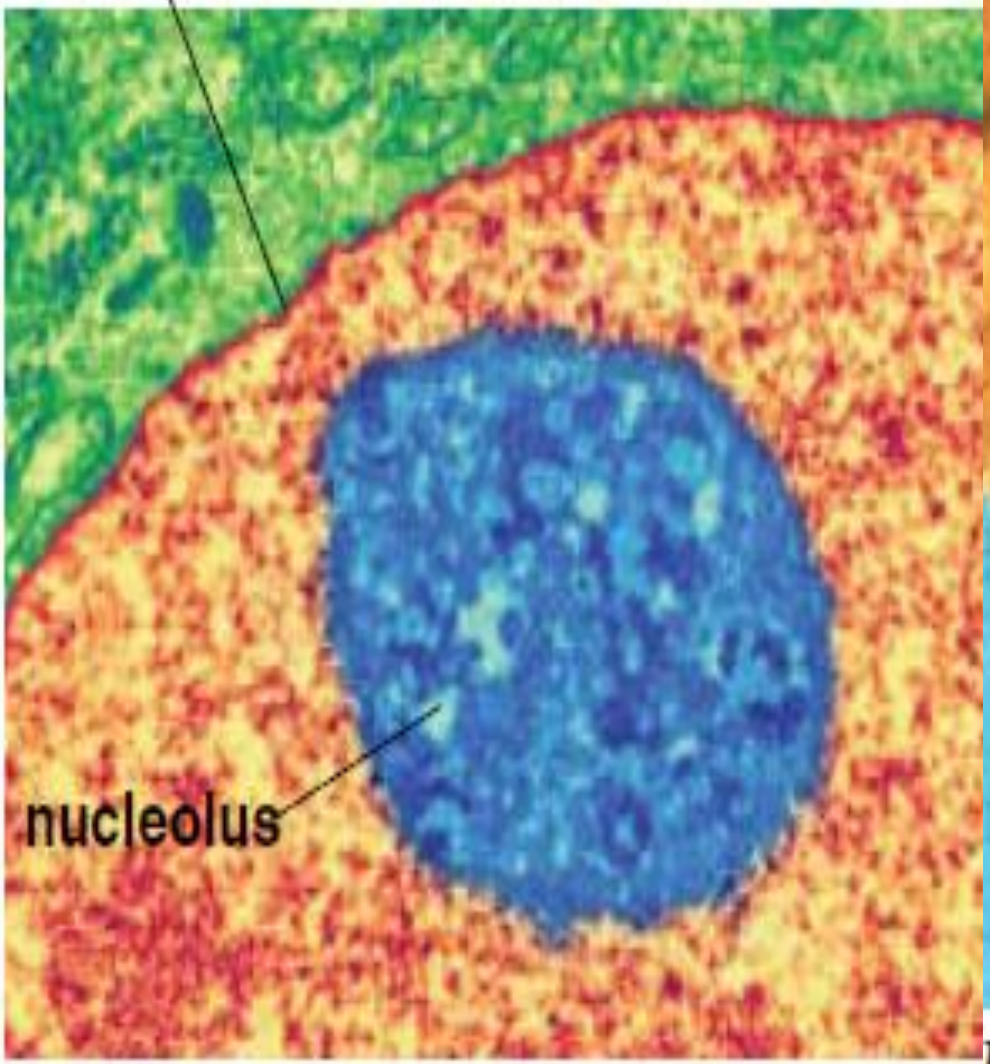



*Figure 4.35 An electron-micrograph of the nucleus*



*Figure 4.36 An electron-micrograph showing pores in the nuclear membrane*

# Mitochondria

- Mitochondria are the sites of most of the reactions of aerobic respiration.
- They are surrounded by two membranes.
- The inner membrane is folded into **cristae** (*partial partitions in mitochondria*) to increase the available surface area.
- Some of the reactions of aerobic respiration take place in the *fluid matrix*. (*where some of the reactions of aerobic respiration take place in mitochondria)*
- The folded inner membrane provides a large surface area for the electron-transport system, which produces most of the ATP.

# The Mitochondrion



# Ribosomes

- Ribosomes are the sites of protein synthesis.
- They can be found free in the cytoplasm, but are also bound to the membrane system of the endoplasmic reticulum, forming rough endoplasmic reticulum.
- Each ribosome comprises two subunits that are made from **rRNA** and **protein**.
- The subunits are manufactured in the nucleolus.
- They leave the nucleus through nuclear pores and combine in the cytoplasm.

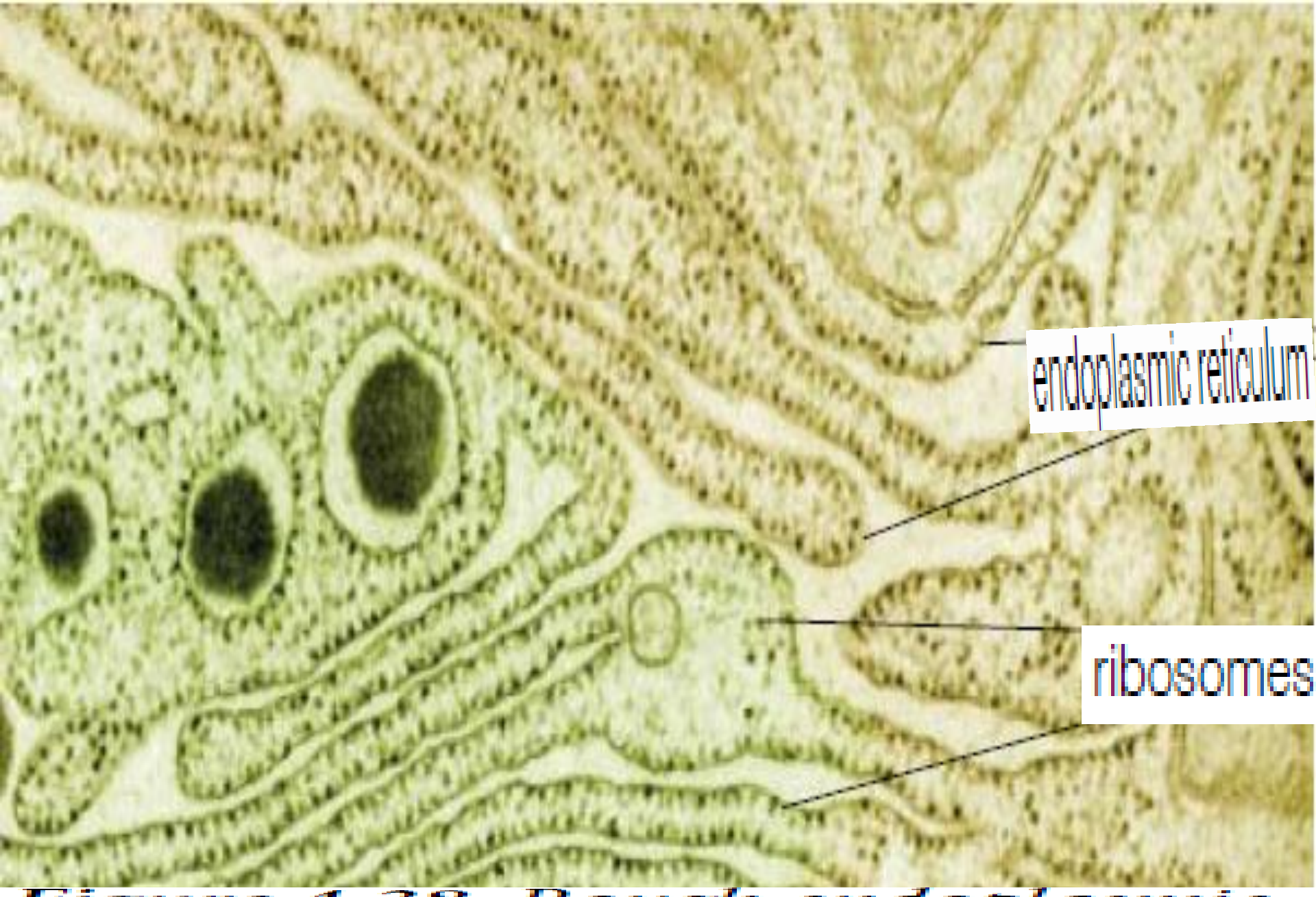
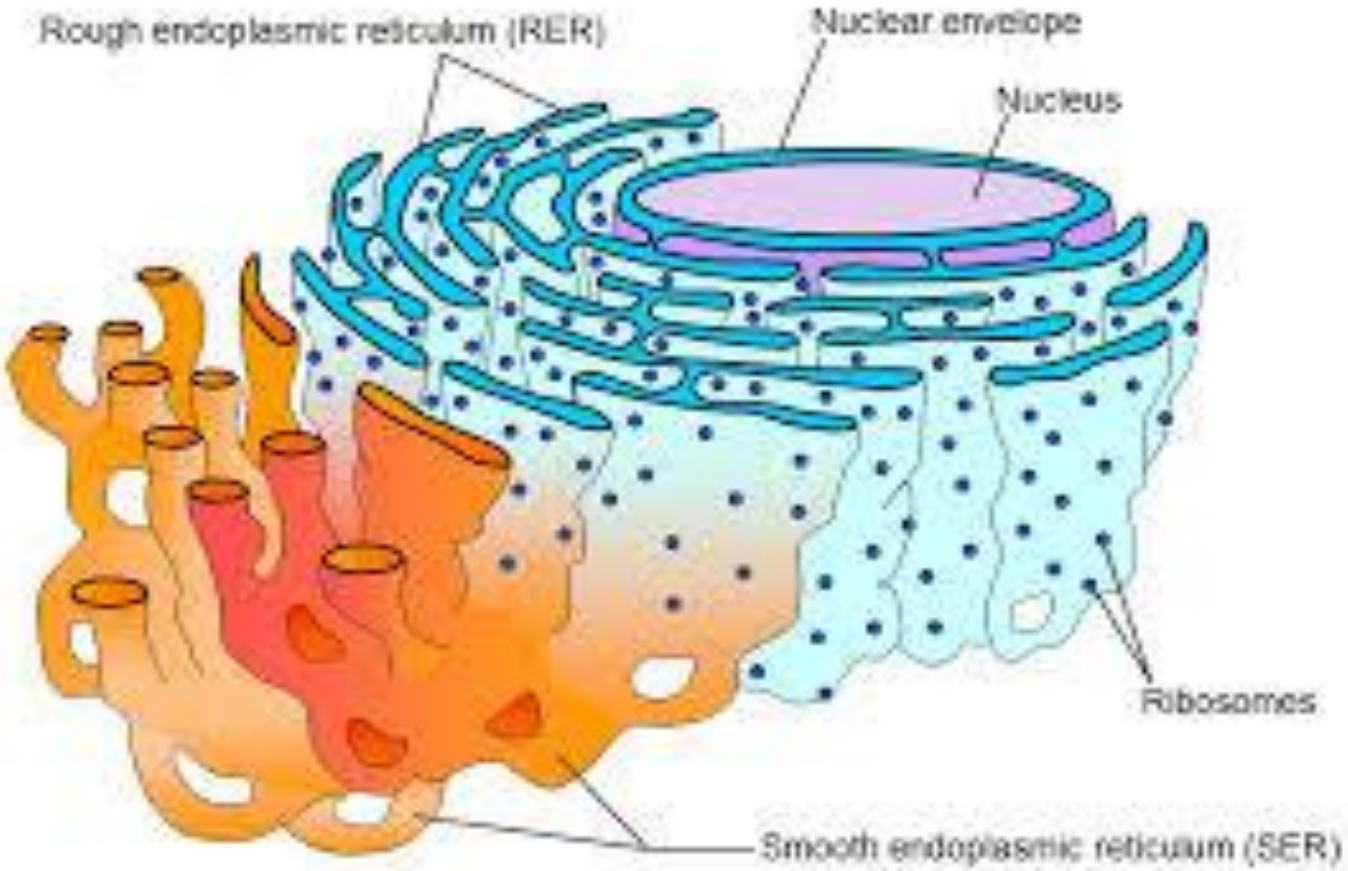



*Figure 4.38 Rough endoplasmic reticulum with ribosomes attached*

# Endoplasmic reticulum

- Endoplasmic reticulum (ER) is a membrane system found throughout the cytoplasm of eukaryotic cells.



# Endoplasmic reticulum

## Rough ER(RER)

- has ribosomes on its surface
- responsible for the manufacture and transport of proteins.

Protein molecules manufactured by the ribosomes pass through small pores into the lumen (inner space) of the ER.

They are then moved in a vesicle to the Golgi body

## Smooth ER (SER)

- has no ribosomes on its surface.
- concerned with the **synthesis of lipids.**
- also associated with carbohydrate metabolism and detoxification

# Golgi apparatus (or Golgi body)

- The Golgi apparatus consists of a number of flattened membrane-bound sacs in which proteins are modified.
- Proteins may be converted into glycoproteins, for example.
- Many of the modifications added in the Golgi apparatus act as a kind of ‘tag’, which determine the final destination of the molecule.
- Many of the modified molecules are released from the Golgi apparatus in vesicles to be carried to other parts of the cell or to the plasma membrane to pass out of the cell by exocytosis to be used elsewhere. Some vesicles form the lysosomes.

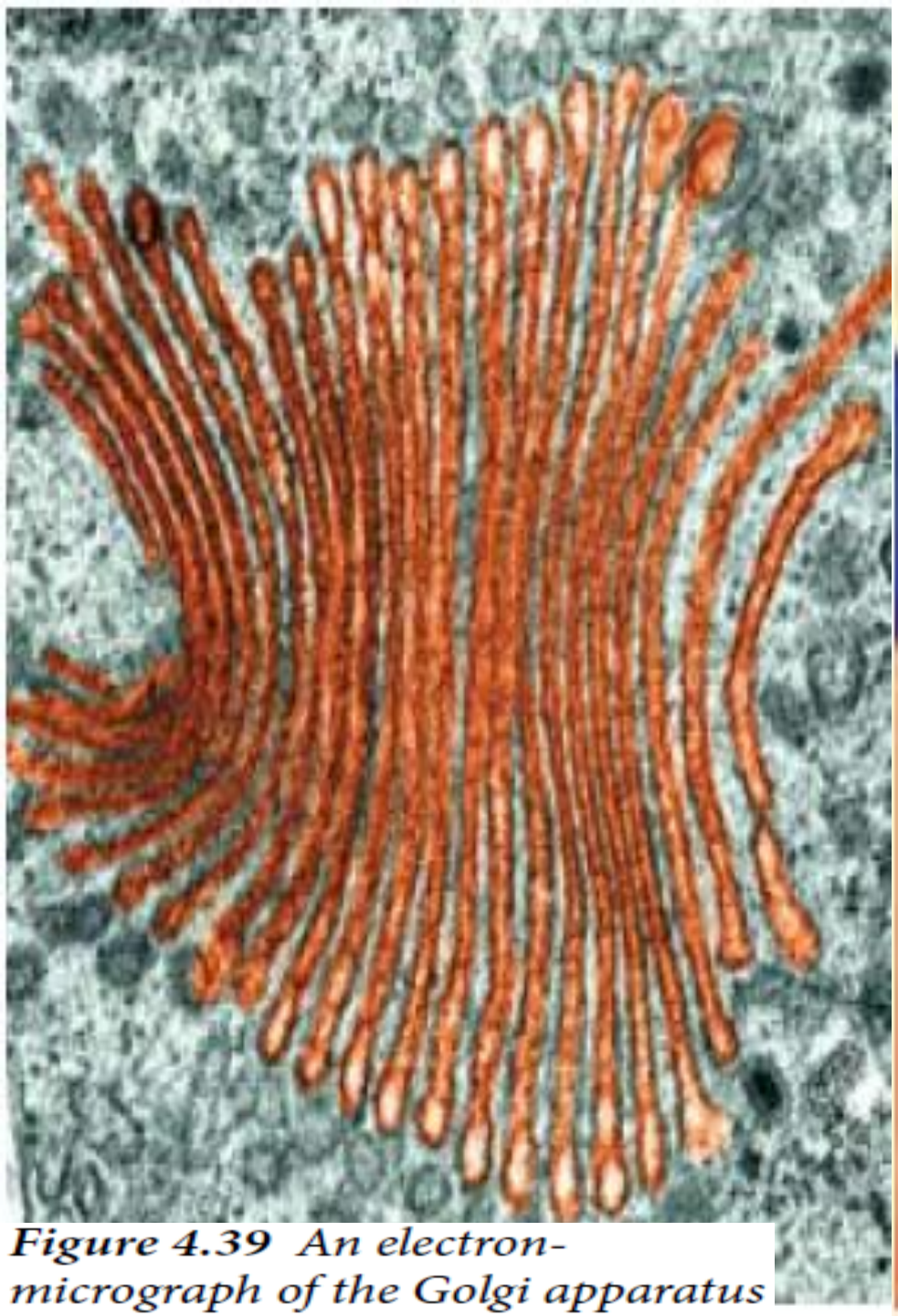


**Figure 4.39** *An electron-micrograph of the Golgi apparatus*



**Figure 4.40** *An artist's impression of the Golgi apparatus*

# Lysosomes- 'suicide bag'

- Lysosomes have no specialised internal structure and are surrounded by a single membrane.
- They are formed in the Golgi apparatus and contain digestive enzymes that break down cellular waste and debris.
- Lysosomes are particularly abundant in phagocytic white blood cells.
- Enzymes from the lysosomes digest foreign cells that have been engulfed.

# Peroxisomes

- Perixosomes are small, membrane-enclosed organelles that contain enzymes involved in a variety of metabolic reactions, including several aspects of energy metabolism.
- Although peroxisomes are morphologically similar to lysosomes, they are assembled, like mitochondria and chloroplasts, from proteins that are synthesized on free ribosome and then imported into peroxisomes as completed polypeptide chains.
- Although peroxisomes do not contain their own genomes, they are similar to mitochondria and chloroplasts in that they replicate by division.

# Organelles found in plant cells

## 1. Cell wall

- The criss-cross arrangement of cellulose fibres in the cell wall gives it both strength and elasticity.
- Because there are large 'gaps' (on a molecular scale) between the fibres, the cell wall is freely permeable

# 2. Vacuole

- The vacuole in a plant cell is a fluid-filled sac that stores a range of solutes.
- It is also important in maintaining the turgidity, or turgor, of a cell.
- When the vacuole is full of liquid (mainly water), it exerts pressure on the cytoplasm and, in turn, on the cell wall.
- If thevacuole loses water by osmosis, the pressure reduces and turgor is lost.
- The cell becomes flaccid (see the section on osmosis).

# 3. Chloroplast

- Chloroplasts are surrounded by two membranes, like mitochondria, but, unlike mitochondria, the inner membrane is not folded.
- There are two main regions in chloroplasts that are linked to the stages of photosynthesis:

a. **membranous regions called grana** (each of which is a stack of thylakoids) where the light-dependent reactions occur, and

b. **a fluid stroma** - where the light-independent reactions occur.

- ***grana*** is membranous regions in a *chloroplast*
- ***Thylakoids*** is flattened sacs inside a chloroplast where photosynthesis takes place

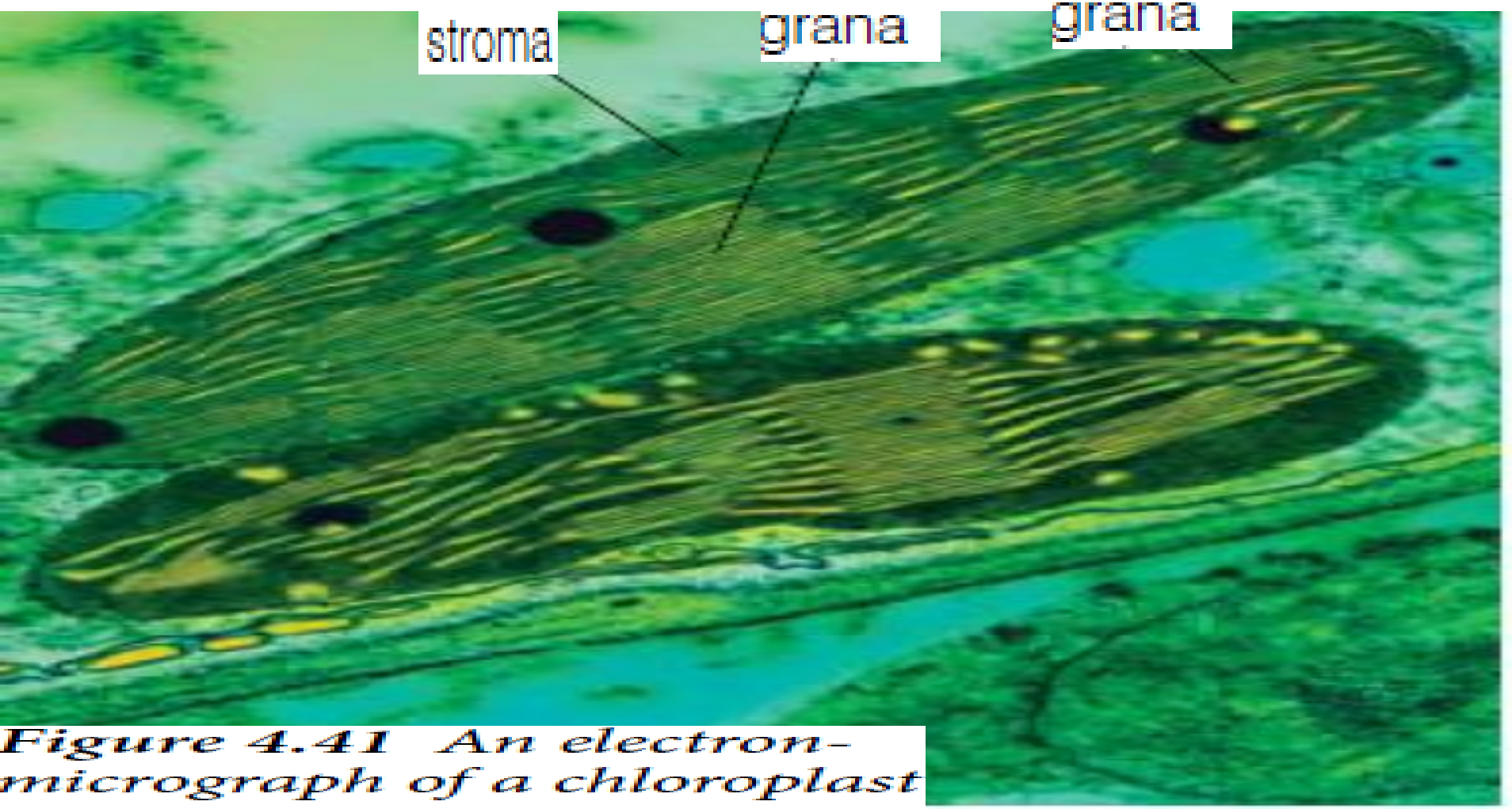
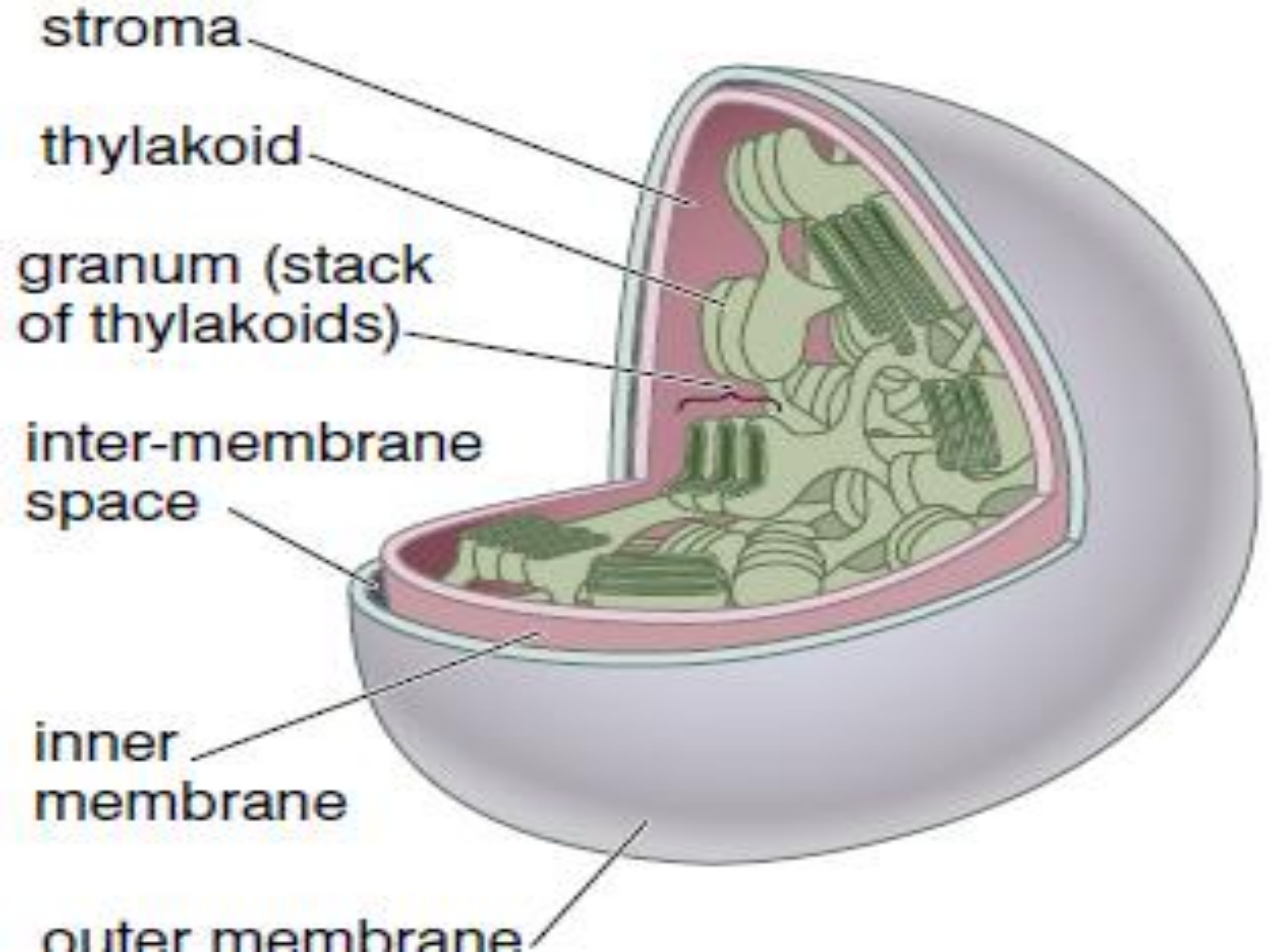



Figure 4.41 An electron-micrograph of a chloroplast


stroma
thylakoid
granum (stack of thylakoids)
inter-membrane space
inner membrane
outer membrane

# How have biologists been able to study the different organelles?

- This has been possible because of a technique called **cell fractionation**.
- The technique is based on the fact that the masses of organelles vary and depend on their size.
- When a mixture of organelles is spun in a centrifuge, the various types settle out at different speeds of spinning.
- The large nucleus requires a relatively low centrifuge speed to make it settle out; the much smaller ribosomes require a much higher speed. The technique is carried out as follows:

1. The cell sample is stored in a suspension that is:

a. **buffered** - the neutral pH prevents damage to the structure of proteins, including enzymes

b. **isotonic** (of equal water potential) - this prevents osmotic water gain or loss by the organelles; gaining too much water could rupture the organelles

c. **cool** - this reduces the overall activity of enzymes released later in the procedure

2. The cells are homogenised in a blender and filtered to remove debris.
3. The homogenised sample is placed in an ultracentrifuge and spun at low speed. The nuclei settle out, forming a pellet.
4. The supernatant (the suspension containing the remaining organelles) is spun at a higher speed - chloroplasts settle out (if plant tissue is used).
5. The supernatant is spun at a higher speed still - mitochondria settle out.
6. The process is repeated at ever higher speeds until all the organelles have been separated

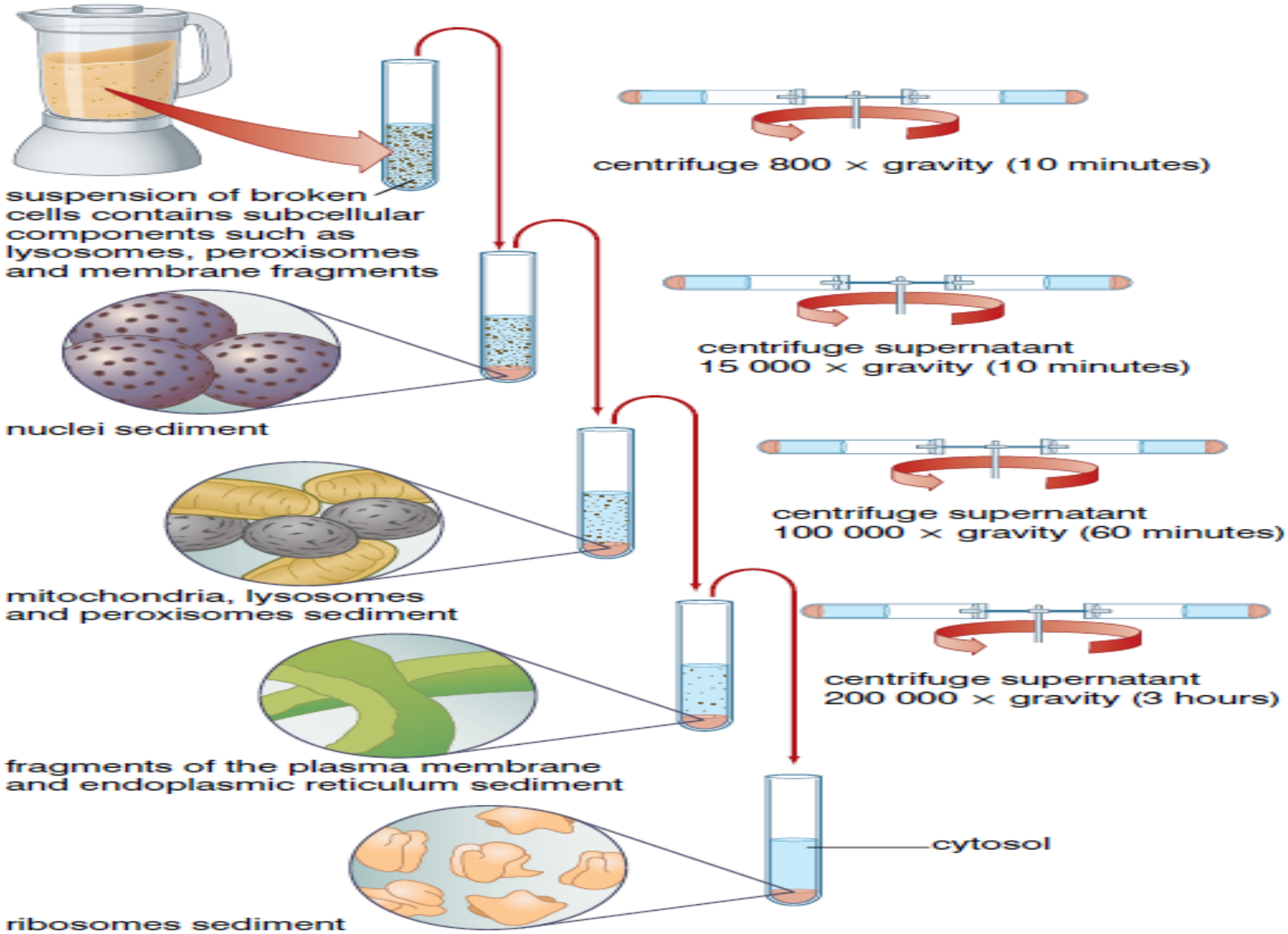



*Figure 4.43 Cell fractionation*


THANK YOU
THE END