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BIOLOGY (REMEDIAL)

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UNIT 1

The Science Of Biology

1.1 The methods of science

1.2 The tools of a biologist

Objectives of the chapter

- ❑ ***By the end of this chapter you should able to:***
 - Define Science as a way of knowledge
 - Describe and explain the main steps scientists follow when they investigate something.
 - Plan and conduct an experiment to investigate a particular observation.
 - Write a report for a scientific experiment.

The Methods of Science

- **Biology** is the science of life and living organisms.
 - ✓ **Organism** is living being made from one cell or many cells

□ What are the sciences of biology?

Biological sciences encompasses all the divisions of natural sciences examining various aspects of vital processes.

The concept includes anatomy, physiology, cell biology, biochemistry and biophysics, and covers all organisms from microorganisms, animals to plants.

- ✓ **Life** is a condition that distinguishes living things from non-living things such as eating, metabolizing, excreting, breathing, moving, growing, reproducing, and responding to external stimuli.

What is Biology?

- Is 'the science of life'. this makes it a pretty big subject!
- Biology seeks to understand how all life functions – including life on other planets, should it exist
- Attempts to give scientific answers to many questions that most people think are important.
 - Where did humans come from?
 - Where did I come from?
 - How do I work?
 - How did all life begin?
 - How is disease caused?
 - How is AIDS caused?

Cont...

- How can vaccines be developed against diseases like malaria and AIDS?
- What makes cancer cells different from ordinary cells?
- Will it ever be possible to grow a new kidney just for me?
- Will people one day live forever?
- What causes global warming?
- How can we solve problems of food shortage?

Cont'd

- **Biologists** are professional who specializes in studying living organisms. **Example:**
 - ***Astrobiologists***- try to find evidence of life on the planet and how life can survive in many different types of environments
 - ***Paleobiologists***- try to find out about the way in which life began on earth and how it evolve from simple life forms into more complex ones.
 - ✓ they use evidence from fossils and from study of chemistry of ancient rock

What is Science?

- The word **Science** is come from Latin word ***Scientia*** w/c means **knowledge**.
- It is a unique system of acquiring knowledge based on the **scientific method**.
 - ✓ ***Scientific method*** is the process by which scientists approach their work.
- **Science sometimes called:**
 - ✓ ***Experimental science***- depend on experimentation to obtain the information.
 - ✓ ***Applied science***- in which scientific research is used to meet certain human needs.

Cont'd

- **Science** is an ongoing effort to find new information and principles which can be increase human knowledge and understanding.
- In their research, ***scientists*** collect evidence that support or disproves a particular suggested explanation of a natural phenomenon.

The Scientific method

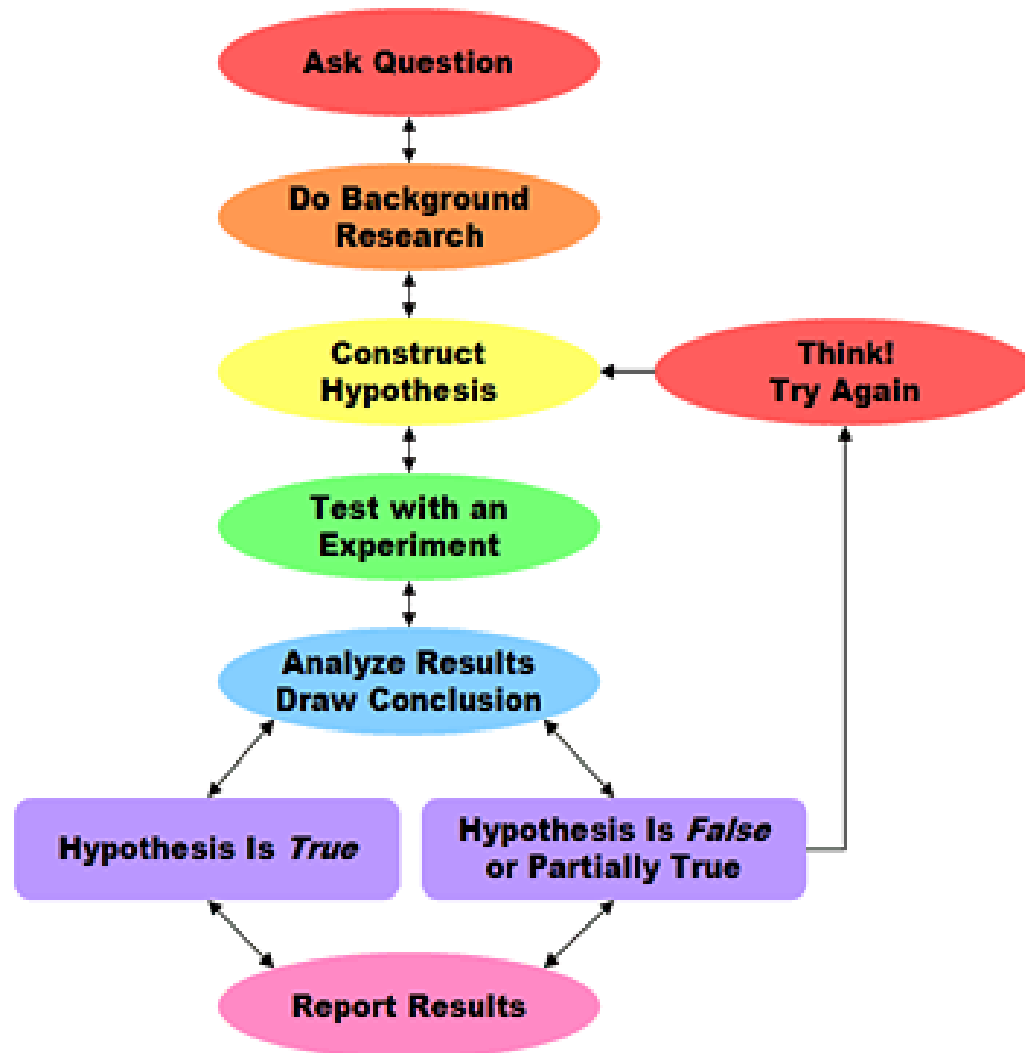
- Is the process by which scientists approach their work.
- For centuries, people based their explanations of what they saw going on in the world around them on observation, without testing their ideas to see if they were true.
- ✓ Example: *spontaneous generation of living organisms*
 - ✓ life has originated from non living organic mater abiogenetically, i.e. , without the intervention of living things

Cont...

- ✓ Suggested that mice could spontaneously generate from non living matter like dirty shirt and grains
 - ✓ worms like flies and beetles could suddenly come from decaying organic matter,
 - ✓ frogs, snakes and crocodiles from mud.
-
- ✓ This theory was latter disproved by a series of experiments conducted by F.Redi, L.Spallanzani and L.Pasteur

The main steps of the scientific method

- The scientific method consists of a number of stages.



Cont'd

Step of the method	What happens at this step
Ask a question	Something catches our imagination. We know that tomato seeds germinate when they are planted. But, why don't tomato seeds grow inside tomatoes?
Do background research	Before we start trying to do the whole investigation ourselves, we will first check scientific magazines and the internet to see if anyone else has looked into the problem, or into a similar problem. We find out that there are substances in plants that control growth, called growth regulators.
Construct hypothesis	There are chemicals in tomatoes that stop the seeds from growing whilst they are still in the tomatoes themselves. Based on our hypothesis, we can make a prediction: 'Seeds covered in tomato juice will not germinate as well as seeds covered in water'.

Cont'd

Design and carry out an experiment to test the hypothesis

- ✓ Put several tomatoes in a blender.
- ✓ Filter (strain) the blended material through some muslin

Analyze results and draw conclusions

- ✓ It seems like something in the tomato juice is affecting the germination of the seeds.
- ✓ It can't be the cells themselves, because they were filtered off. It must be a chemical in the juice

Accept or reject the hypothesis

Report results

- ✓ We must now decide whether or not to report the results to other biologists.
- ✓ Someone else might decide to take the work further and try to isolate a particular chemical from the many in the juice to find exactly what is stopping them from growing inside the tomato itself.

Control group and experimental group

- ✓ A **control group** acts as a 'standard' for comparison. It is used to 'isolate' the factor we are investigating and show that changes are due to this factor.
- ✓ For example, in drug trials, one group of people with the condition the drug is used to treat is given a tablet containing the drug (the experimental group). Another group is given a placebo – a tablet containing no drug (the control group).
- ✓ If both groups get better, then it seems that the drug is having little effect. If only the experimental group get better, this must be due to the drug. Without the control group we wouldn't have been sure.

- **Control group** the standard group in an experiment in which the experimental groups are compared with
- **Experimental group** the group in an experiment which is being experimented on in order to compare with the control group

How did the scientific method disprove the idea of spontaneous generation?

- In 1668 an Italian biologist, Francesco Redi,
- He used wide-mouth jars containing meat.
 - ✓ Some jars were left open to the air.
 - ✓ Others were covered with a piece of gauze.
- After several days, maggots and then flies could be seen in the open jars, but none appeared in the closed jars.
- Redi was able to conclude that flies cannot be produced from rotting meat.

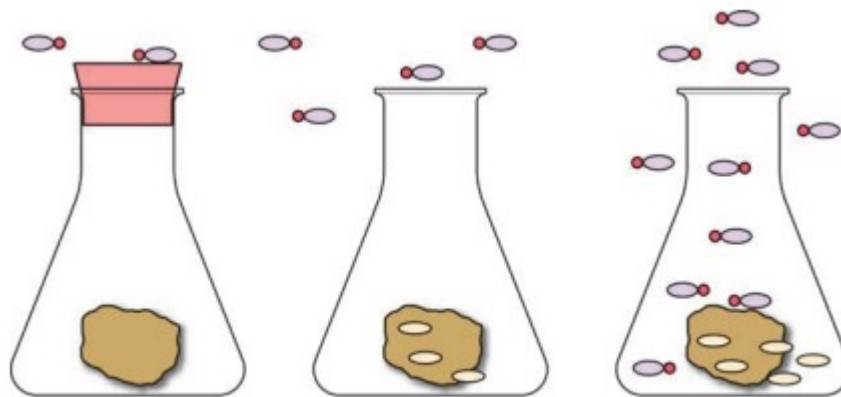


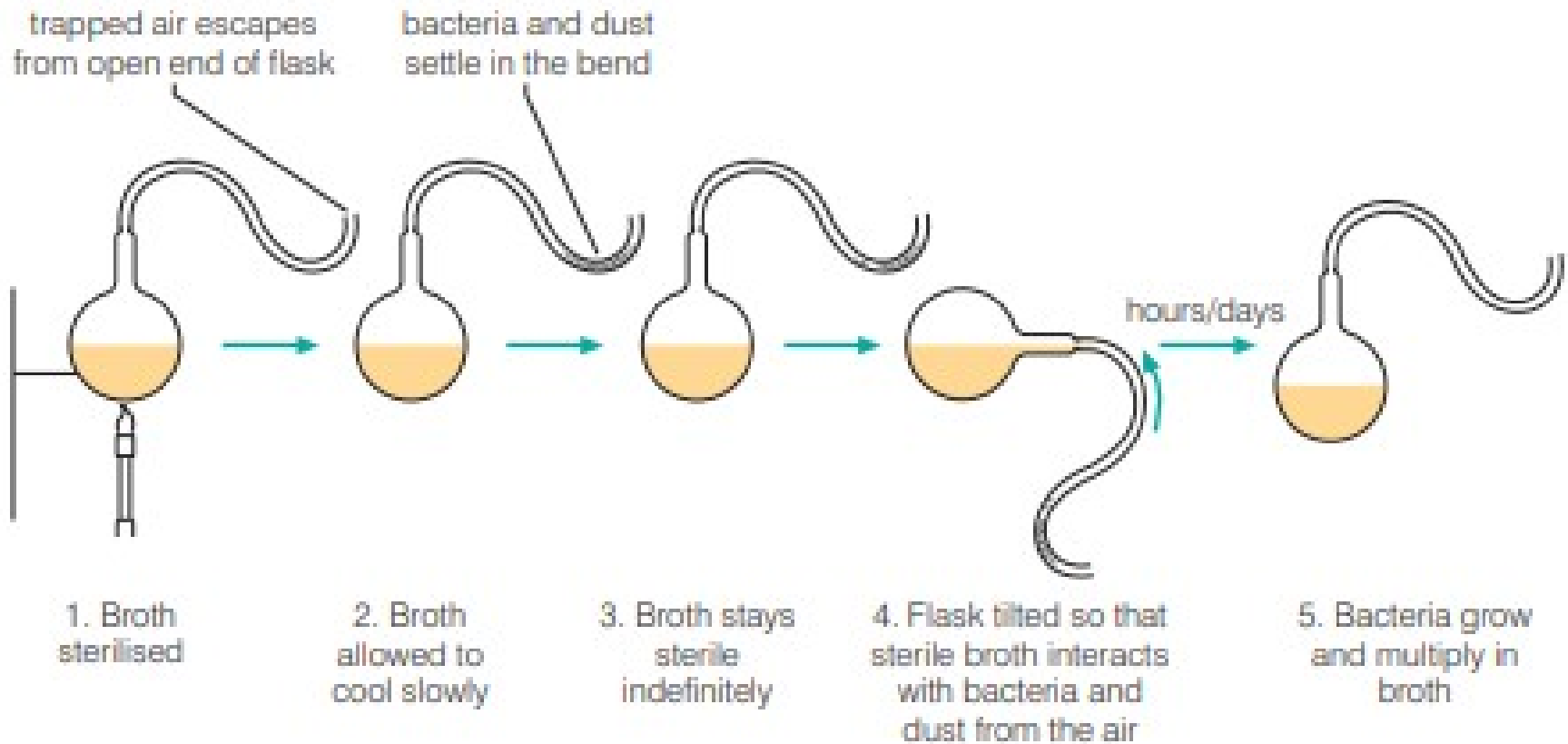
Figure Francesco Redi's 1668 experiment

Cont'd

- Redi's experiment was accepted by most people for larger organisms. However, Many people still believed that microorganisms could arise by spontaneous generation
- In 1859, Pasteur carried out experiments to show that the micro-organisms that caused wine and broth to go cloudy came from the air and were not made from the broth itself.
 - ✓ He used special 'swan-necked fasks

Cont'd

- Pasteur found that the broths stayed clear for months. At the end of this time, he treated the flasks in one of three ways:
 - ✓ He left some of them as they were.
 - ✓ He broke the necks on some.
 - ✓ He tilted others to allow the dust in the low part of the neck to mix with the broths



The broths in the second two groups of flasks turned cloudy (due to the presence of micro-organisms) within days. The broths in the first group remained clear. After this, people were forced to admit that spontaneous generation, even of micro-organisms, could not happen.

What do we mean by cause and effect?

- Scientific experiments try to establish cause and effect.
 - This means that they try to prove that a change in one factor brings about a change in another factor.
- A **variable** is anything that can take on different values.
- ❖ **Control variable:** quantities that scientists want to remain constant observe as controlled variable

Variable

❖ **Dependent variable:** is the factor that the scientist measures to see if it changes when the IV is changed.

✓ can not be manipulated by the experimenter

❖ **Independent variable:** is the factor that the scientist changes, or manipulates.

Eg. 2: in an experiment why tomato seeds don't germinate inside tomatoes:

Eg.1: Effect of temperature on plant pigmentation.

Cont'd

- In the tomato seed example, if one group of seeds had been at a higher temperature than the other group, this could have made them germinate faster. We wouldn't have known whether it was the tomato juice affecting the results or the temperature. Our experiment would not be valid. So we must keep constant anything other than the IV that might influence the results. These are controlled variables. In the tomato seed experiment, the controlled variables were: • temperature • lighting conditions • number of seeds per dish, and • volume of liquid added (water or tomato juice).

Cont'd

- ❖ **Confounding variable:** is a variable that might influence the results that you can't control
- For example, if you measure the carbon dioxide uptake by wheat plants as the light intensity changes over the day, you cannot control the effect of change in temperature. It could be a confounding variable

Accuracy, reliability and validity in scientific experiments

- **Accuracy** refers to how precisely you measure or count something.
- ✓ For example, you could measure time with a clock, a wristwatch or a stop-clock accurate to 0.01 seconds. The level of accuracy you choose must reflect the magnitude of what you are measuring. You don't always need the most accurate measuring instrument.
- ✓ To measure volume: E.g. a syringe, a measuring cylinder, a pipette, a burette

Reliability

- is a measure of how dependable and consistent the results of an experiment are
 - ✓ If we were to repeat the investigation, would we get more or less the same results?
 - ✓ There are several things we can do to increase the reliability of our experiments.

Validity

- This is about whether or not our experiment measures what it says it is measuring. In the tomato seed experiment, we said that our results were due to the presence or absence of tomato juice. For our experiment to be valid, we must be certain that our results were only due to the changes in the independent variable and nothing else. So had we not controlled all the other variables, our experiment would not have been valid.

How do we write reports on scientific experiments?

- It is important, then, that the layout of the report is recognizable to everyone and understandable by everyone.
- there is a set way to lay out such a report. It is not always identical in every case, but there are certain 'rules' to follow.

Cont...

There must be:

- **a title**, which states clearly what is being investigated
- **a hypothesis**, stated clearly in terms of how the independent variable is expected to influence the dependent variable, often extended to a prediction for the particular experiment
- **a clear description of the experimental procedure**; this must be in such detail that anyone of the same level of understanding could easily replicate the procedure and it must include:
 - the apparatus used (a diagram of the assembled apparatus is useful)
 - details of any chemicals used; what volumes or concentrations or masses were used
 - details of any organisms used (for example, yeast, mice) – what strain and how many
 - details of any control experiments

Cont...

- **A full account of the results obtained;** it is often helpful to summarise these (where appropriate) in graphs, charts and tables
- **The conclusions that have been drawn from the results**
- **An evaluation of the procedure;** this is an honest assessment of the limitations of the procedure that has been used, pointing out any unavoidable limitations and inaccuracies that arose
- **An acknowledgement of the use of any other person's work;** this is usually done by identifying by a number the place in the report where other work has been used, and then listing the sources at the end of the work

1.2 The tools of a biologist

What do biologists use in the laboratory?

This is still a large list. But there are some basic tools. These include:

- microscopes
- dissecting equipment
- Petri dishes
- pipettes and syringes
- centrifuges
- measuring cylinders
- balances

MICROSCOPE

- Types of Microscopes
- Care
- Parts
- Focusing

Cont...

- **optical microscopes** that use beams of light to produce magnified images
- **electron microscopes** that use beams of electrons to produce magnified images

Light microscopes vary from basic microscopes that can be used in the laboratory and even taken out and used in the field to very sophisticated microscopes that are linked to image-enhancing computer programs to produce all kinds of images that help to make the image clearer.

Of course, biologists also use electron microscopes that give much higher magnifications and, importantly, much higher resolution, so that more detail can be seen.

Microscope Resolution

Resolution is the ability to distinguish between two points that are close together.

If resolution is poor, they will merge into one point and the detail of the image will be limited.

Electron microscopes have a much higher resolution than optical microscopes.

Types of Microscopes

Light Microscope - the models found in most schools, use compound lenses to magnify objects. The lenses bend or refract light to make the object beneath them appear closer.



Common magnifications:
40x, 100x, 400x

*Oil Immersion lenses can
improve quality of focus
and magnification

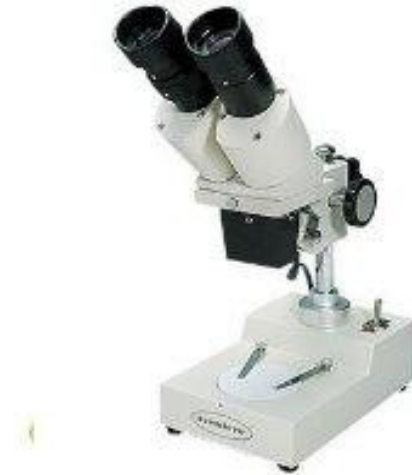
Stereoscope

This microscope allows for binocular (two eyes) viewing of larger specimens. Also requires light to create the image.

Usually magnifies 10x to 20x

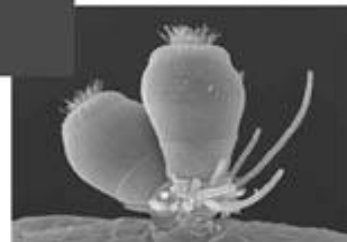
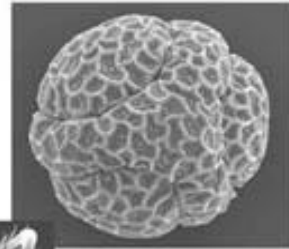
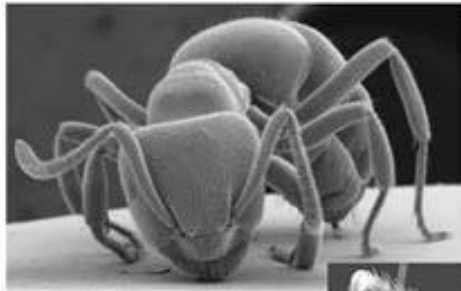
Can be used for thicker specimens

Creates a 3D view of specimen



Scanning Electron Microscope - allows scientists to view a universe too small to be seen with a light microscope. SEMs do not use light waves; they use electrons (negatively charged electrical particles) to magnify objects up to two million times.

SEM creates a 3D view of specimen, but cannot view living specimens (process kills them)



**Transmission
Electron
Microscope** - also
uses electrons, but
instead of scanning
the surface (as with
SEM's) electrons are
passed through very
thin specimens.

TEM = "thin"



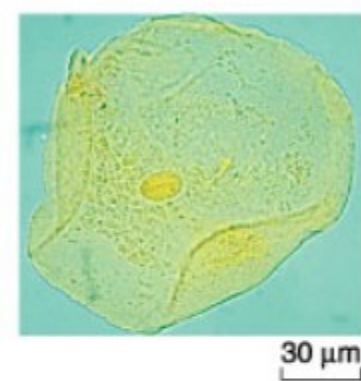
TEM of a cell, notice you see the inside of the cell and not the surface.



Types of Illumination in Microscopes

How light passes through a specimen changes the view of the specimen, making some parts more distinct.

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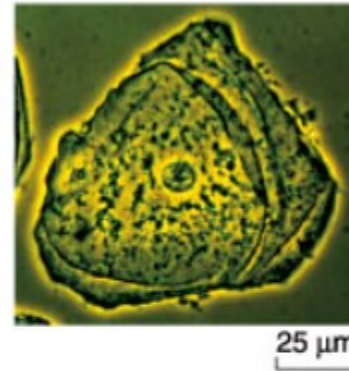
Bright-field. Light passing through the specimen is brought directly into focus. Usually, the low level of contrast within the specimen interferes with viewing all but its largest components.



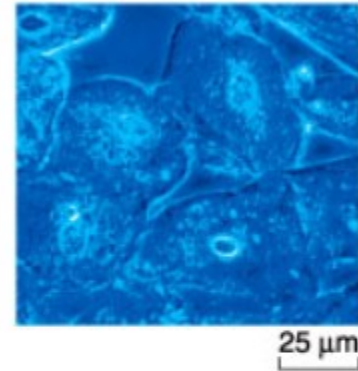
Bright-field (stained). Dyes are used to stain the specimen. Certain components take up the dye more than other components, and therefore contrast is enhanced.



Differential interference contrast. Optical methods are used to enhance density differences within the specimen so that certain regions appear brighter than others. This technique is used to view living cells, chromosomes, and organelle masses.



Phase contrast. Density differences in the specimen cause light rays to come out of "phase." The microscope enhances these phase differences so that some regions of the specimen appear brighter or darker than others. The technique is widely used to observe living cells and organelles.



Dark-field. Light is passed through the specimen at an oblique angle so that the objective lens receives only light diffracted and scattered by the object. This technique is used to view organelles, which appear quite bright against a dark field.



30 μm

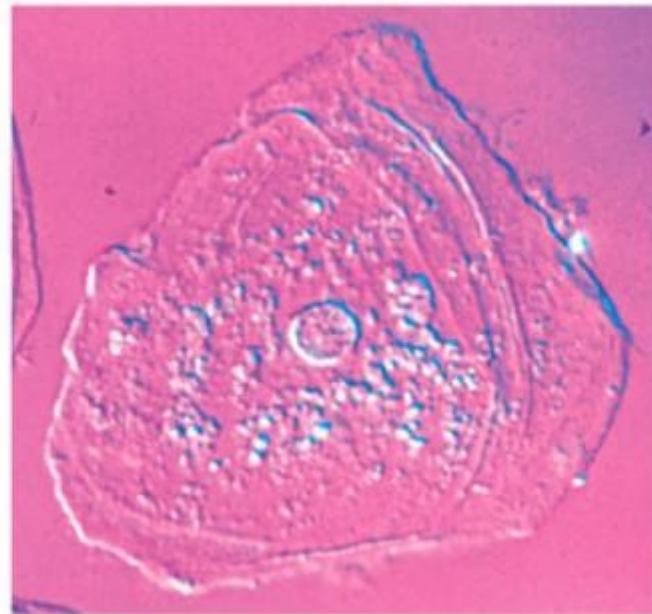
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30 μm

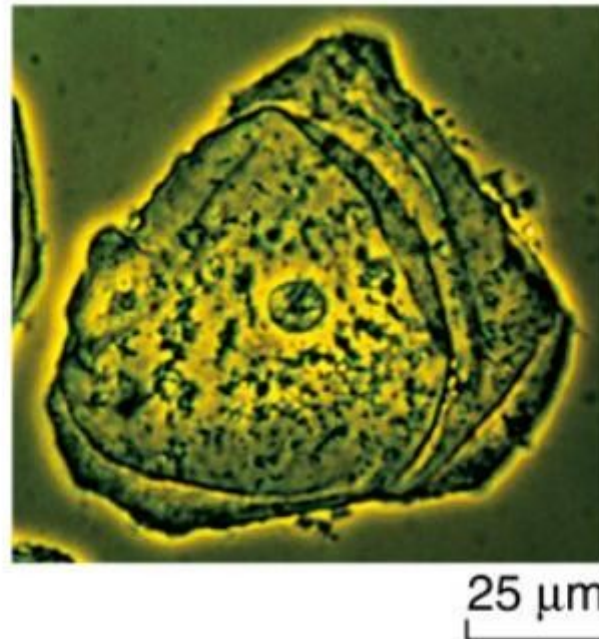
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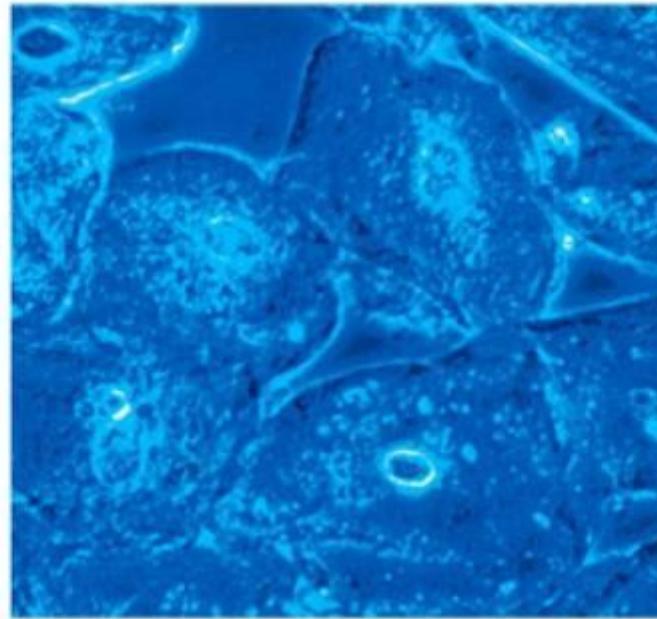


25 μm

Differential interference contrast. Optical methods are used to enhance density differences within the specimen so that certain regions appear brighter than others. This technique is used to view living cells, chromosomes, and organelle masses.



Phase contrast. Density differences in the specimen cause light rays to come out of “phase.” The microscope enhances these phase differences so that some regions of the specimen appear brighter or darker than others. The technique is widely used to observe living cells and organelles.



25 μm

Dark-field. Light is passed through the specimen at an oblique angle so that the objective lens receives only light diffracted and scattered by the object. This technique is used to view organelles, which appear quite bright against a dark field.

The Light Microscope

Guidelines for Use

- Always carry with 2 hands
- Only use lens paper for cleaning
- Do not force knobs to turn
- Always store covered
- Keep objects clear of desk and cords



Microscope Parts

Eyepiece

Body Tube

Revolving Nosepiece

Objective Lens

Arm

Stage Clips

Stage

Diaphragm

Coarse Focus

Light

Fine Focus

Base

Magnification

Your microscope has 3 magnifications: Scanning, Low and High. Each objective lens will have written the magnification. In addition to this, the ocular lens (eyepiece) has a magnification.

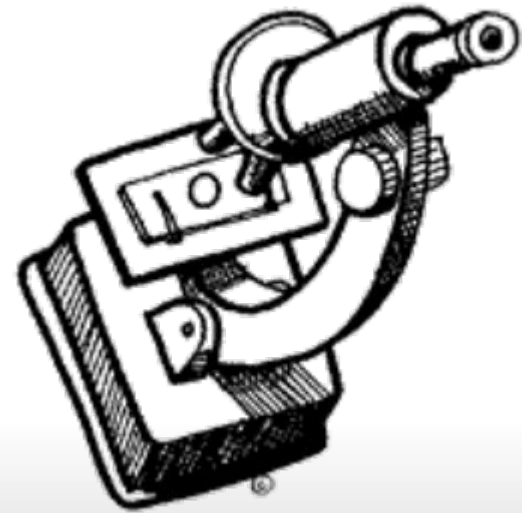
The total magnification is the eyepiece lens x objective lens!!

	Magnification	Ocular lens	Total Magnification
Scanning	4x	10x	40x
Low Power	10x	10x	100x
High Power	40x	10x	400x

Using the Microscope

General Procedures

1. Make sure all backpacks and junk are out of the aisles and off the tops of desks.
2. Plug your microscope in to the extension cords. Each row of desks uses the same cord.
3. Store with cord wrapped around microscope and the scanning objective clicked into place.
4. Carry by the base and arm with both hands.

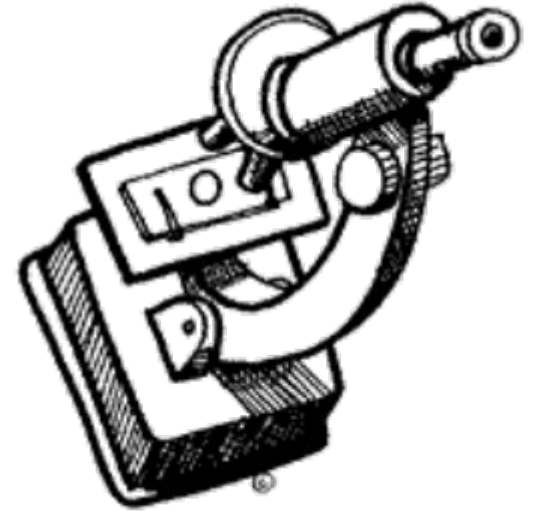


Focusing Specimens

1. Always start with the scanning objective.

Odds are, you will be able to see something on this setting. Use the Coarse Knob to focus, image may be small at this magnification, but you won't be able to find it on the higher powers without this first step.

Do not use stage clips, try moving the slide around until you find something.



2. Once you've focused on Scanning, switch to Low Power. Use the Coarse Knob to refocus. Again, if you haven't focused on this level, you will not be able to move to the next level.

3. Now switch to High Power. (If you have a thick slide, or a slide without a cover, do NOT use the high power objective). At this point, ONLY use the Fine Adjustment Knob to focus specimens.

**DO NOT SKIP
STEPS!!!!**

Recap

- 1. Scanning --> use coarse knob**
- 2. Low power --> use coarse knob**
- 3. High power --> use fine knob**

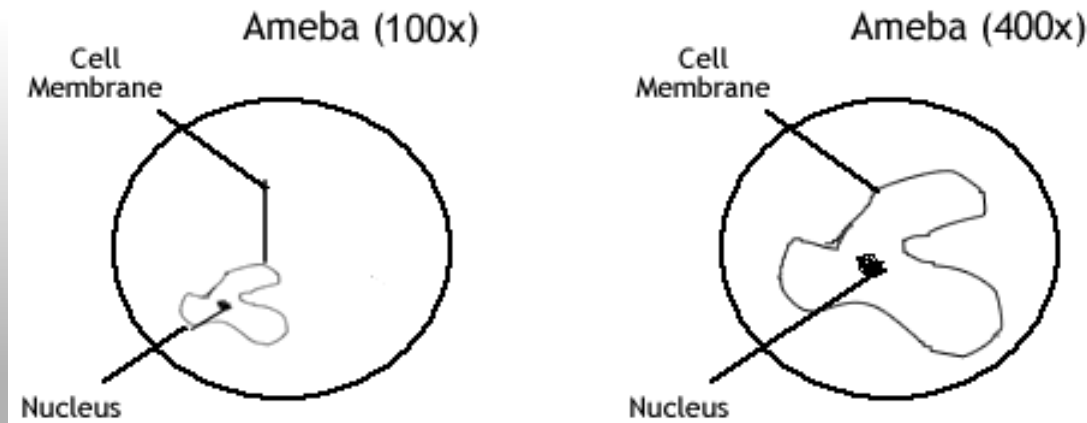
Using High Power

- Your slide **MUST** be focused on low power before attempting this step
- Click the nosepiece to the longest objective
- Do **NOT** use the Coarse Focusing Knob, this could crack the slide or the lens
- Use the Fine Focus Knob to bring the slide into focus



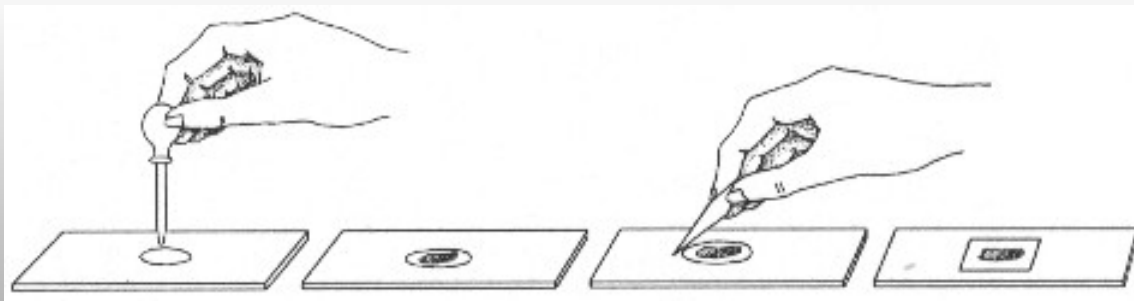
Drawing Specimens

1. Use pencil - you can erase and shade areas
2. All drawings should include clear and proper labels (and be large enough to view details). Drawings should be labeled with the specimen name and magnification.
3. Labels should be written on the outside of the circle. The circle indicates the viewing field as seen through the eyepiece, specimens should be drawn to scale - ie..if your specimen takes up the whole viewing field, make sure your drawing reflects that.



Making a Wet Mount

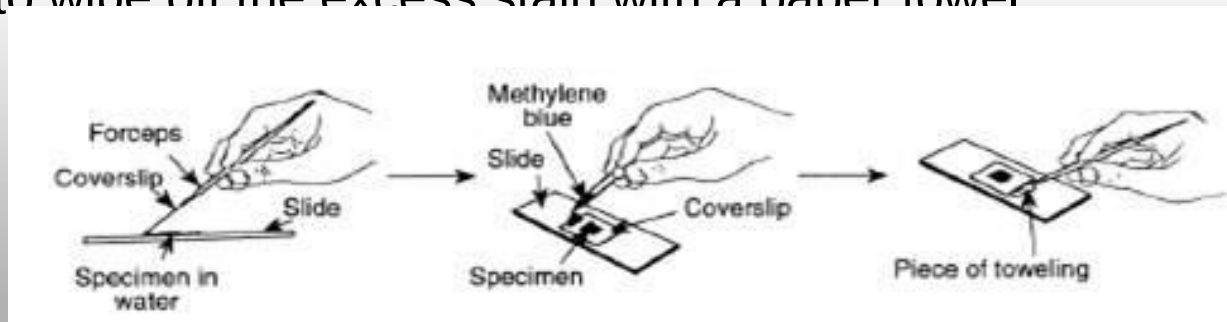
1. Gather a thin slice/peice of whatever your specimen is. If your specimen is too thick, then the coverslip will wobble on top of the sample like a see-saw, and you will not be able to view it under High Power.
2. Place ONE drop of water directly over the specimen. If you put too much water, then the coverslip will float on top of the water, making it hard to draw the specimen, because they might actually float away. (Plus too much water is messy)
3. Place the cover slip at a 45 degree angle (approximately) with one edge touching the water drop and then gently let go. Performed correctly the coverslip will perfectly fall over the specimen.



Do not drop vertically, set one edge down and let the other side drop.

How to Stain a Slide

1. Place one drop of stain (iodine, methylene blue..there are many kinds) on the edge of the coverslip.
2. Place the flat edge of a piece of paper towel on the opposite side of the coverslip. The paper towel will draw the water out from under the coverslip, and the cohesion of water will draw the stain under the slide.
3. As soon as the stain has covered the area containing the specimen, you are finished. The stain does not need to be under the entire coverslip. If the stain does not cover as needed, get a new piece of paper towel and add more stain until it does.
4. Be sure to wipe off the excess stain with a paper towel



Cleanup

1. Store microscopes with the scanning objective in place.
2. Wrap cords and cover microscopes.
 - *Double check to make sure you didn't leave a slide
3. Wash slides in the sinks and dry them, placing them back in the slide boxes to be used later.
4. Throw coverslips away. (these are not reusable)
 - *Be careful not to drop these in the sink, they can clog drain.
5. Place microscopes in their designated location (probably a cabinet)

Troubleshooting

Occasionally you may have trouble with working your microscope. Here are some common problems and solutions.

1. Image is too dark!

Adjust the diaphragm, make sure your light is on.

2. There's a spot in my viewing field, even when I move the slide the spot stays in the same place!

Your lens is dirty. Use lens paper, and only lens paper to carefully clean the objective and ocular lens. The ocular lens can be removed to clean the inside. The spot is probably a spec of dust.

3. I can't see anything under high power!

Remember the steps, if you can't focus under scanning and then low power, you won't be able to focus anything under high power. Start at scanning and walk through the steps again.

4. Only half of my viewing field is lit, it looks like there's a half-moon in there!

You probably don't have your objective fully clicked into place..

Cont'd

▪ What do Biologists use in the fields?

- ✓ To gain an estimate of the abundance of organisms in an area, biologists often use **quadrats**.
- They study different areas to find out how the animals, plants and microorganisms interact with each other and with the environment.
- They find out how an area changes over time and how it is influenced by human activity. All this involves:
 - taking measurements of the abundance of organisms in the field
 - taking samples of the environment (for example, soil, rocks, water) for analysis in the laboratory
 - collecting specimens for identification and analysis in the laboratory

Cont...

□ quadrat a small frame used for ecological or population studies.

➤ This data can be used to make an estimate of the abundance of the organisms in the area

➤ Biologists also use quadrats to show how the numbers of a particular species changes across an area

UNIT 2

2.1. INORGANIC MOLECULES

2.2. ORGANIC MOLECULES

- By the end of this section you should be able to:
 - Group biochemical molecules as inorganic and organic.
 - Explain which chemical elements are found most often in biochemical molecules.
 - Describe the properties of water.
 - Explain the importance of water to living organisms

Classification of inorganic and organic molecules

Biological molecules can be classified into **two** main types:

- **Inorganic molecules**
 - **Organic molecule**
-
- ❖ Organic molecules always contain both **carbon** and **hydrogen**.
 - ❖ Inorganic molecules may contain one or the other (or neither), but not both

Can you see that the organic molecules always contain both carbon and hydrogen?

- Different organic molecules contain different combinations of carbon and hydrogen. They may also contain other chemical elements.
- Most biological organic molecules contain oxygen in addition to carbon and hydrogen and some also contain nitrogen



What is an
organic
compound
?

- What is so
special
about
Carbon?

- Compounds containing
C, H, O and often N, P,
& S.

- Organic compounds
make up all living
things and are
necessary for life.

- It can combine to form
long chains which act
as the backbone of
large molecules.

- **Macromolecules** –

Table 2.1 *Examples of inorganic and organic molecules*

Some inorganic molecules	Some organic molecules
Calcium carbonate CaCO_3	Glucose $\text{C}_6\text{H}_{12}\text{O}_6$
Carbon dioxide CO_2	Glycine (an amino acid) $\text{C}_2\text{H}_5\text{NO}_2$
Water H_2O	Linoleic acid (a fatty acid) $\text{C}_{18}\text{H}_{32}\text{O}_2$
Iron III oxide Fe_3O_4	Methane CH_4

Overview: Carbon: The Backbone of Life

- Although cells are 70–95% water, the rest consists mostly of **carbon-based compounds**
- **Carbon** is unparalleled in its ability to form large, complex, and diverse molecules
- **Proteins, DNA, carbohydrates**, and other molecules that distinguish living matter are all composed of **carbon compounds**

The Chemical Groups Most Important in the Processes of Life

- **Functional groups** are the components of organic molecules that are most commonly **involved in chemical reactions**
- The **number** and **arrangement** of functional groups give each molecule its unique properties

-
- The **seven functional groups** that are most important in the chemistry of life:
 - Hydroxyl group
 - Carbonyl group
 - Carboxyl group
 - Amino group
 - Sulfhydryl group
 - Phosphate group
 - Methyl group

Which chemical elements are found most frequently in living organisms?

- The elements that used to build nearly all biological molecules are **Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus** and **Sulphur**.
- Very few other elements are used to build biological molecules, although other elements do have specific functions in biological systems.

The most common elements in many cells are:

Hydrogen (H) 59%

Oxygen (O) 24%

Carbon (C) 11%

Nitrogen (N) 4%

Others (such as phosphorus (P) and sulphur (S)) 2% combined

(The percentages given are averages for many different cells.)

Cont'd

- Some elements that are important for humans are
 - calcium (Ca) for bones, teeth and muscles,
 - chlorine (Cl) for digesting food,
 - fluorine (F) for tooth enamel and
 - iron (Fe) to help blood carry oxygen around the body.
- Atoms of elements can join together to form molecules. We call this forming a chemical bond. Sometimes two atoms of the same element join together to form a molecule of that element.
- Atoms of one element can join with atoms of another element to make a molecule of a compound.

cont'd

Each atom can make a certain number of bonds with other atoms; this is called its valency.

Table 2.2 The number of bonds (valencies) of atoms of the elements most commonly used to build biological molecules.

Element	Number of bonds formed (valency)
Carbon (C)	4
Hydrogen (H)	1
Oxygen (O)	2
Nitrogen (N)	3
Sulphur (S)	2 (sometimes 4 or 6)
Phosphorus (P)	5

atoms *the smallest particles of a chemical element*

bond *the energy that joins atoms together to form a molecule*

molecule *a number of atoms bonded together*

compound *a substance made from molecules containing more than one kind of atom in a fixed ratio*

valency *the number of bonds an atom can make with other atoms*

- So, whilst a carbon atom can bond with four hydrogen atoms, each hydrogen atom can only bond with one carbon.
- Because carbon can bond with four other atoms, it can make large molecules with chains of carbon atoms. These are the organic molecules that are the basis of life.

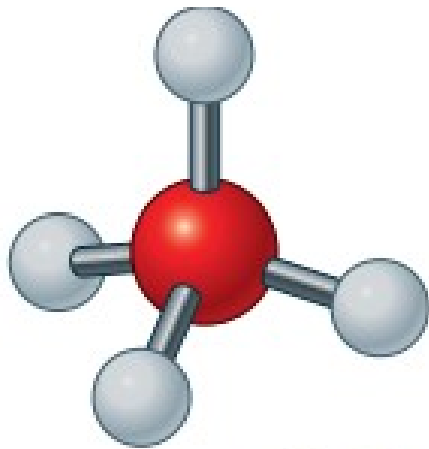


Figure 2.2 The structure of methane. In a molecule of methane, a carbon atom bonds with four hydrogen atoms. Each hydrogen atom only bonds with one carbon atom.

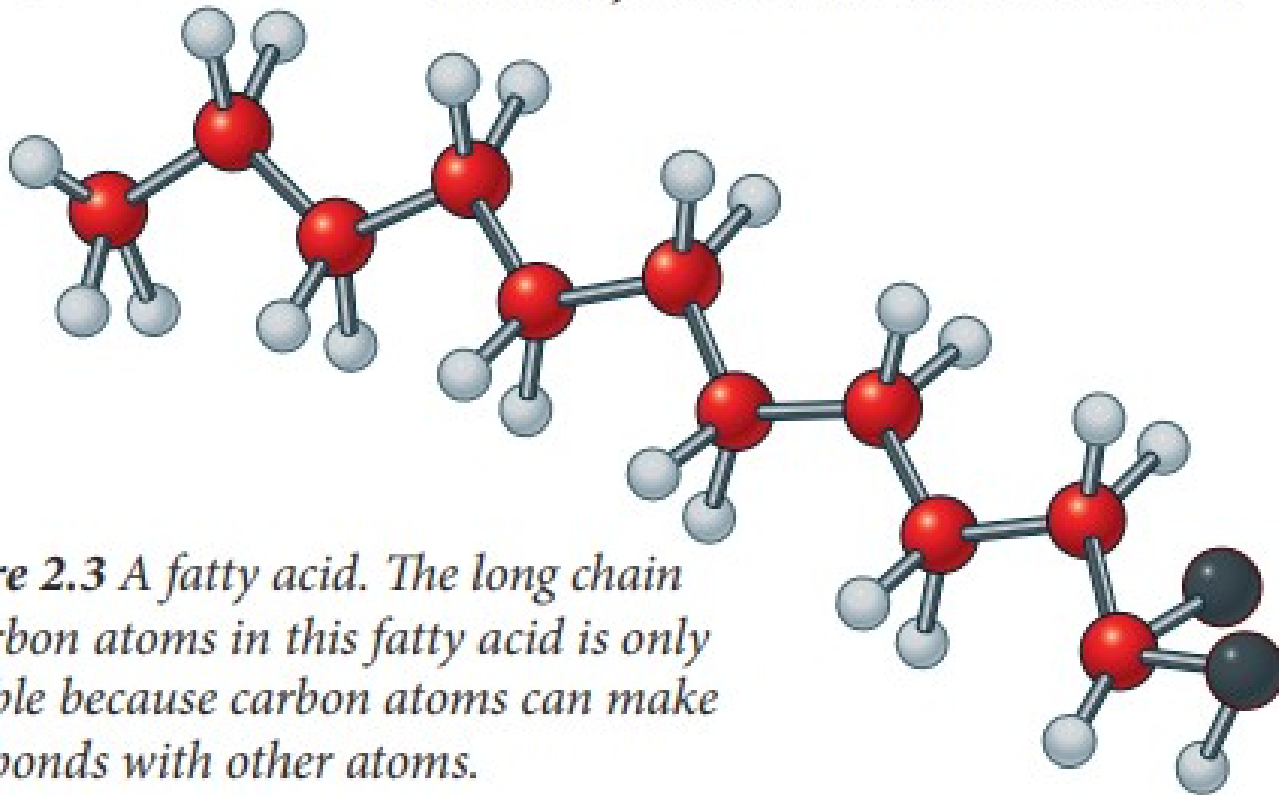


Figure 2.3 A fatty acid. The long chain of carbon atoms in this fatty acid is only possible because carbon atoms can make four bonds with other atoms.

Water

Water covers three-quarters of the planet and on the remaining one-quarter, which is land, It may be in streams, rivers, ponds, lakes or in huge underground aquifers. And, of course, it is in all living things.

- ✓ Most cells are about 70% water and
- ✓ some are as high as 90%.

What is water?

- Made of two hydrogen atoms bonded to one oxygen atom.
- The molecule is not 'straight' it is bent into a 'v' shape.
- Also, the molecule forms what we call a 'dipole'.
- Part of the molecule has a slight negative charge (δ^-) and other parts have a slight positive charge (δ^+).
- What is less well known is that in a mass of water (such as the water in a glass or the water in a pond),
- all the water molecules are interlinked! Besides the bonds joining the hydrogen atoms to the oxygen atom, there are very weak bonds – called hydrogen bonds –

Cont...

- That join the oxygen in one water molecule (the slightly negative part) to the hydrogen in another water molecule (the slightly positive part).
- It is the only substance that exists in three states – solid, liquid and gas – at temperatures commonly found on Earth.
 - Solid water is ice,
 - liquid water we call water and
 - gaseous water is steam

Cont'd

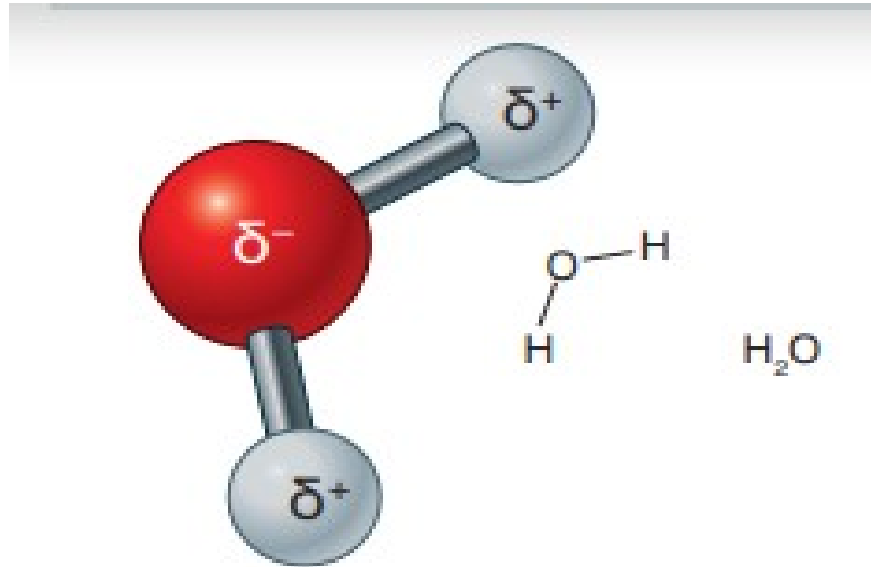
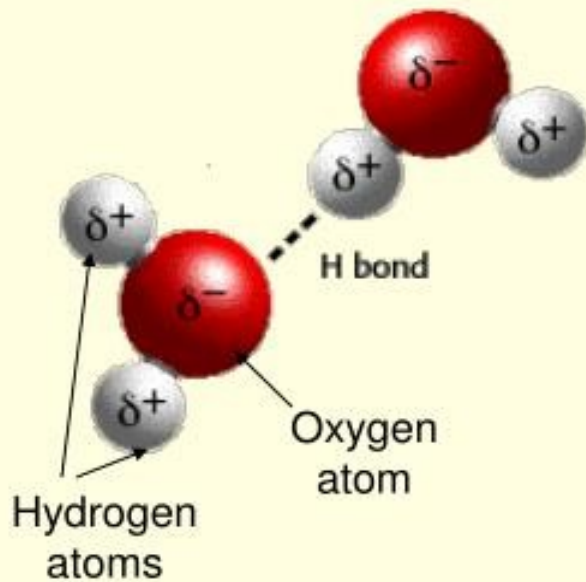


Figure 2.5 A molecule of water

- A bond that joins the oxygen in one water molecule to the hydrogen in another is **hydrogen bond**.

Water's Polarity makes it a Good Solvent

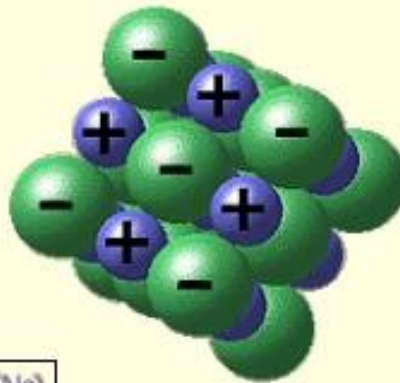
Hydrogen bonding
between water molecules



[Click to see water in motion!](#)

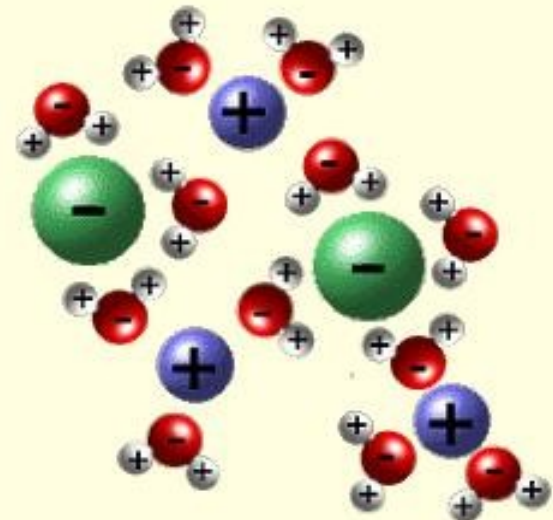
Salt (Sodium Chloride)
dissolving in water:

NaCl crystal structure



sodium (Na)
chlorine (Cl)

NaCl in water



Why is water so important to living things?

- The very first cells on Earth evolved in water about 3.5 billion years ago.
- It is important to living things in a number of ways,
 - a place to live-
 - a transport medium- nutrients
 - a reactant in many chemical reactions
 - a place for other reactions to take place-In chemical reactions
 - water is a vital chemical constituent of living cells

Water cont'd

Important in:

- ❖ Aid in removing wastes from the body
- ❖ Lubricates joints, digestive tracts and body tissues
- ❖ Regulates body temperature

Water is a place to live in.

- ❑ Plants and algae both live in water as do many different types of animals

The Importance of Water

Water is vital to all living organisms, it makes up 80% of cells, is used in transporting substances, is needed for metabolic reactions (like R/P) and helps with temperature control.

Properties of Water:

Polar – the negatively charged Oxygen atom and positively charged Hydrogen atoms

Cohesion – the negative & positive ends of water molecules cause them to attract to each other and form Hydrogen bonds (H bonds)

High **Surface Tension** – acts like it has a skin

High Specific Heat Capacity – it takes a lot of energy to heat it up (amount of energy needed to raise 1g by 1°C)

High Latent Heat – needs a lot of heat energy to evaporate it

Maximum **Density at 4°C** – means ice floats (less dense than liquid form)

Water is transparent

- ❑ This means that light can pass through the water and allow the plants and algae to photosynthesize.
- ❑ It also means that animals can see where they are going.
 - However, water does not allow all light to pass through it and as we go deeper and deeper, less and less light penetrates

Cont'd

Different wavelengths of light penetrate to different depths. Red and indigo wavelengths are soon lost. Blue and green wavelengths penetrate deeper than others.

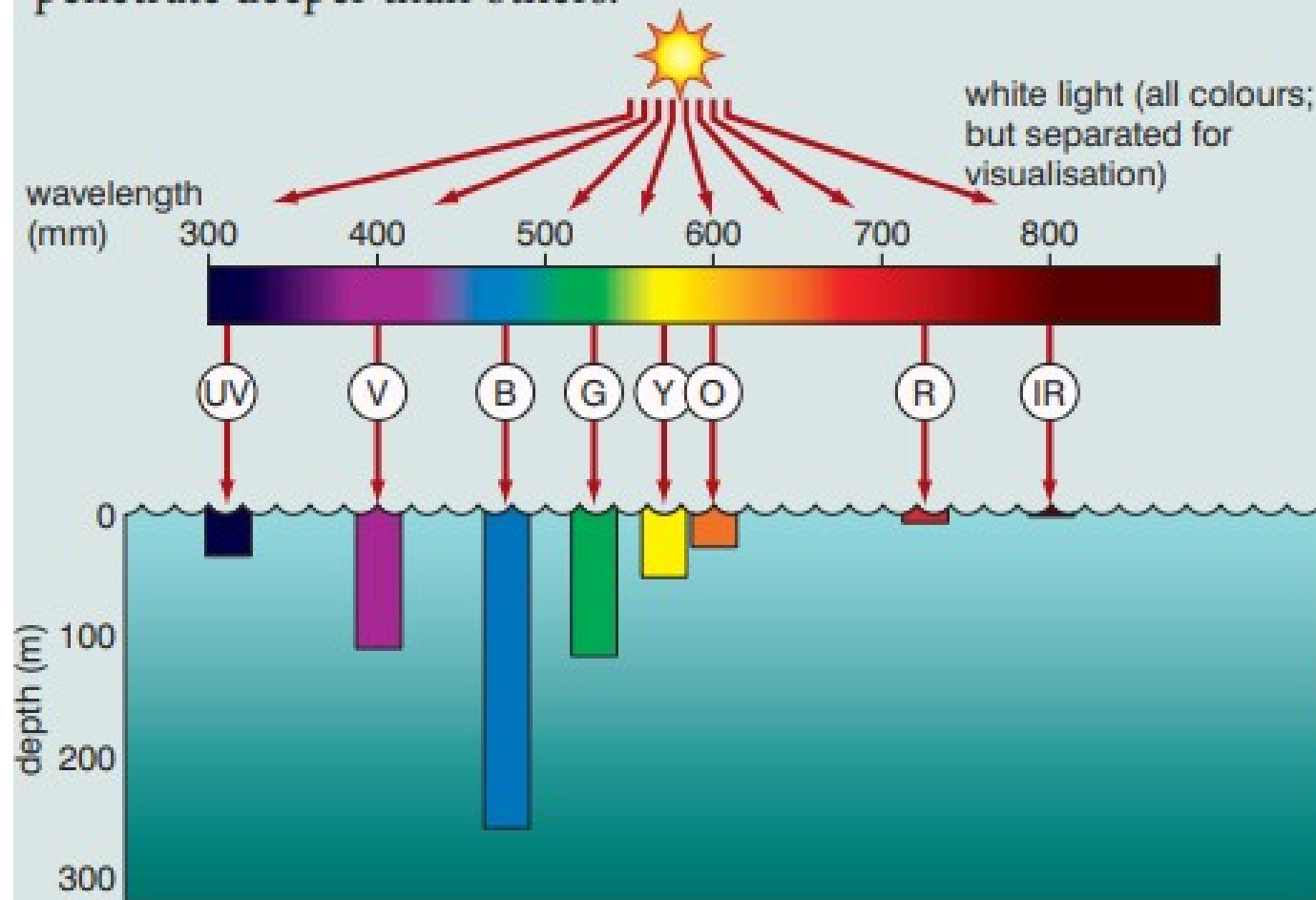


Figure 2.8 Penetration of different wavelengths of light

Water has a high specific heat capacity

- ❖ This means that it takes quite a lot of energy to heat water up.
- ❖ Also loses heat quite slowly. This has the overall effect that water stays more or less the same temperature – particularly large masses of water, such as oceans and lakes.
- ❖ This is important as the functioning of enzymes in living cells is affected by temperature.
 - ✓ Too hot or too cold and the enzymes do not function efficiently and the reactions in the cells controlled by the enzymes are not carried out efficiently.

Ice is less dense than liquid water

- It is unusual for the solid form of a substance to float on the liquid form of the same substance, but ice floats on water.
 - This is because water expands when it freezes. So, in cold weather, water freezes from the top down.
 - The ice on the surface then acts as an insulator and slows down the heat loss from the liquid water underneath.
 - So life can continue in relatively warm water underneath the ice all through the cold weather

Water has a high latent heat of vaporization

- This means that it takes a lot of energy to turn liquid water into water vapour (or steam).
- In turn this means that water doesn't vaporise too easily and that ponds don't dry up too quickly in hot weather – and the organisms in the pond have a better chance of survival. This property is also important in temperature control.
- When we sweat, the energy needed to vaporize the sweat comes from our bodies. This heat is then lost from our bodies and so we cool down. If water vaporized easily, sweating wouldn't be as effective in controlling our body temperature.

Water has a high surface tension.

- The water molecules in the main body of a mass of water are H-bonded to other water molecules on all sides.
- But at the surface, there is no H-bonding above. So the 'pull' from the sides is stronger than it would otherwise be and the molecules at the surface are held together more strongly.
- This is why some animals can 'walk on water' and why others can attach themselves to the surface of the H₂O and live just below the surface.

Cont...

- The water strider in figure 2.10 is just one example of an insect that is so light that the force of the surface tension of the H₂O can support the weight of the insect.



Figure 2.10 A water strider walking on water

The m

Water is a good solvent

- Many organic and inorganic substances important to life dissolve in water, but don't dissolve either at all or as well in other liquids.
- Water is very versatile. Because these substances dissolve in water, they can be transported in a water-based transport medium.
- Biological mechanisms such as active transport, diffusion and facilitated diffusion move the substances into and out of the water (in the transport medium).
- In mammals, the plasma of blood is 90% water. This is forced through the system of veins arteries and capillaries by the heart.
- In plants water carries dissolved minerals upwards from the roots to other parts of the plants in the xylem vessels. Water in the phloem tubes carries dissolved organic substances all over the plant.

Water has the ideal viscosity for a transport medium

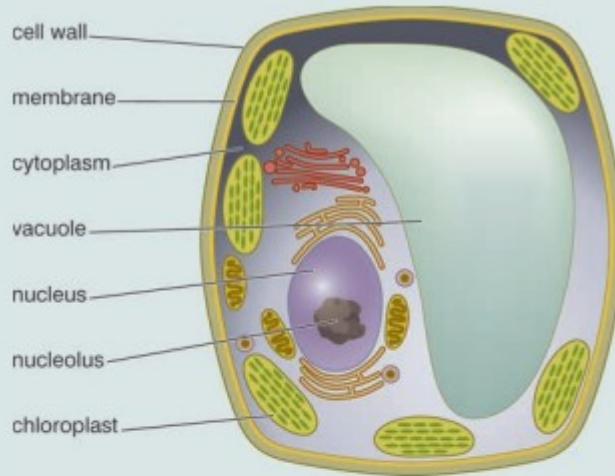
- Viscosity-measure of how fluid a liquid is – how easily it flows.

If water were more viscous (less fluid) than it is – think of tar! – then the heart would not be able to move it through the blood vessels. Also, the water inside cells transports substances around the cell; if it were more viscous, it would damage the delicate organelles in the cells.

If water were less viscous (more fluid) than it is, it would flow too easily and, inside cells, the organelles would not be supported. Similarly, in the circulatory system, a less viscous liquid would not move the blood cells around the system as efficiently.

Cont'd

Water and support in cells



When plant cells absorb a lot of water, they swell until their cellulose cell wall won't let them swell any more. In this condition, we say they are turgid. Turgid cells press against each other and this pressure helps to support the plant. If the cells lose water, the pressure decreases and so does the support.

Figure 2.12 A turgid plant cell



Figure 2.13
A A well-watered coleus plant



B A coleus plant that has not been well-watered

Water as a reactant.

- Many reactions in living things need water as a raw material.
- E.g.. Photosynthesis – process of energy transfer between living things – requires water as one of its reactants.
- No water, no photosynthesis.
- Water is also involved in digesting large food molecules into smaller ones.
- Reactions that use water to split large molecules are called **hydrolysis**

Water molecules are used to split large food molecules into smaller ones that can be absorbed into the bloodstream

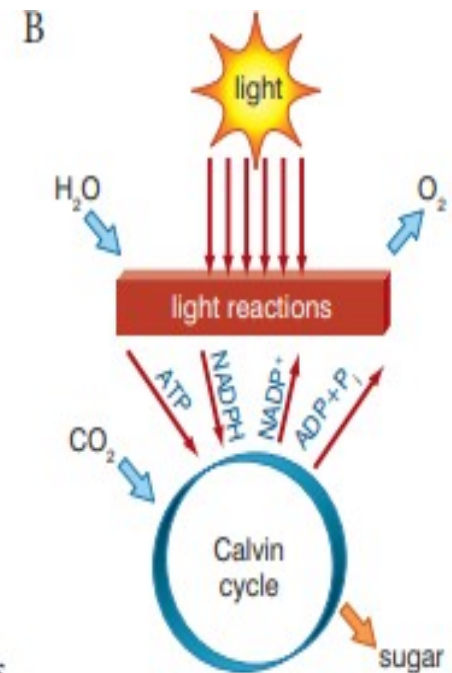
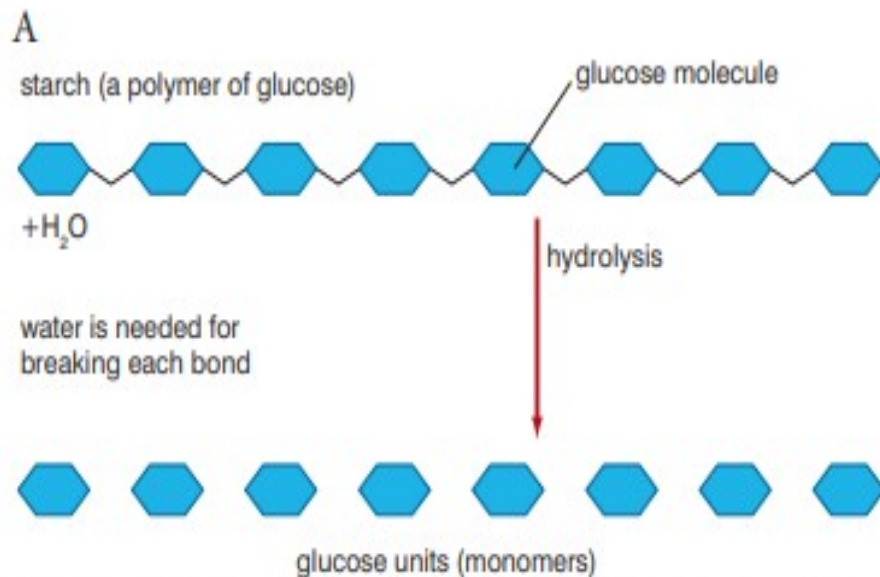


Figure 2.14 *A The hydrolysis of starch B A summary of photosynthesis*

Cont...

- Water is also involved in other reactions.
- eg., it is involved in reactions with carbon dioxide in red blood cells that are important in the transport of carbon dioxide around the body as hydrogen carbonate ions

Water as a medium for chemical reactions

- Cells function because of the many chemical reactions that are continually taking place in them.
- Many of these take place on the membrane systems of the cell, but others take place in the liquid ‘cytosol’ of the cytoplasm.
- Also, many of the reactions of photosynthesis and respiration take place in the liquid inner regions of chloroplasts and mitochondria.

Cont...

- ❑ Water is an ideal medium for these reactions – for some of the reasons already discussed:
 - It can dissolve many substances – the reactions will only take place effectively in solution.
 - It has a low viscosity – the particles can move around and come easily into contact with each other.

So, we can see that, without water, life as we know it could not possibly exist. Water is just too important.

Minerals

- Minerals are inorganic compounds used by the body as building material, and involved with metabolic functions.
 - ✓ Eg., **iron** is needed to make hemoglobin and it binds to hemoglobin in red blood cell.
 - ✓ **Calcium** is an important component of bones and is involved with muscle and nerve functions and they serve as cofactors for enzymes.
 - ✓ **Magnesium** is an important component of the green pigment, chlorophyll, involved in photosynthesis.

2.2 Organic molecules

By the end of this section you should be able to:

- List and describe the structures of organic molecules in living things and state their functions.
- Show the structures and functions of biological molecules using chemical formulae and examples.
- Identify biologically important compounds by conducting simple food tests.
- Appreciate how biological molecules are obtained from different foods.

Learning Outcomes

- Distinguish among monosaccharides, disaccharides and polysaccharides.
- Describe the formation and breakage of glycosidic bond.
- Compare storage polysaccharides (starch and glycogen) with structural polysaccharides (cellulose), and relate these structures to their functions in living organisms.

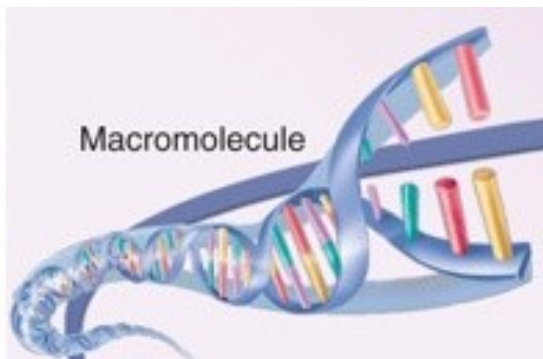
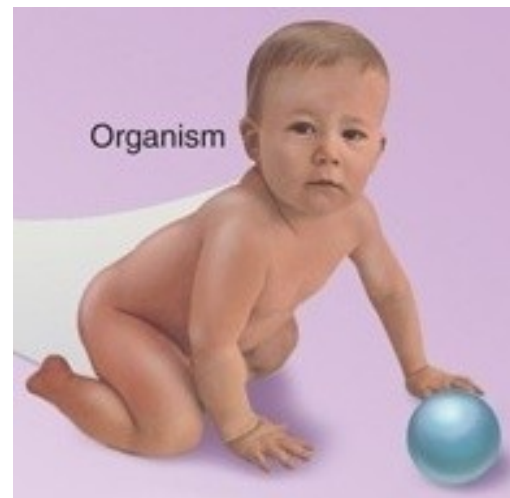
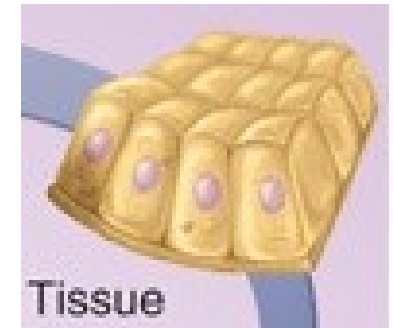
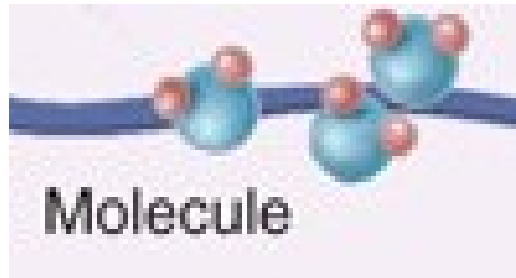
Learning Outcomes

- Analyze and distinguish among triglyceride, phospholipids, fats, and steroids, and describe the structural composition, characteristics, and biological functions of each.
- Explain the meaning of the terms primary structure, secondary structure, tertiary structure and quaternary structure of proteins, and describe the types of bonding which hold the molecules in shape.

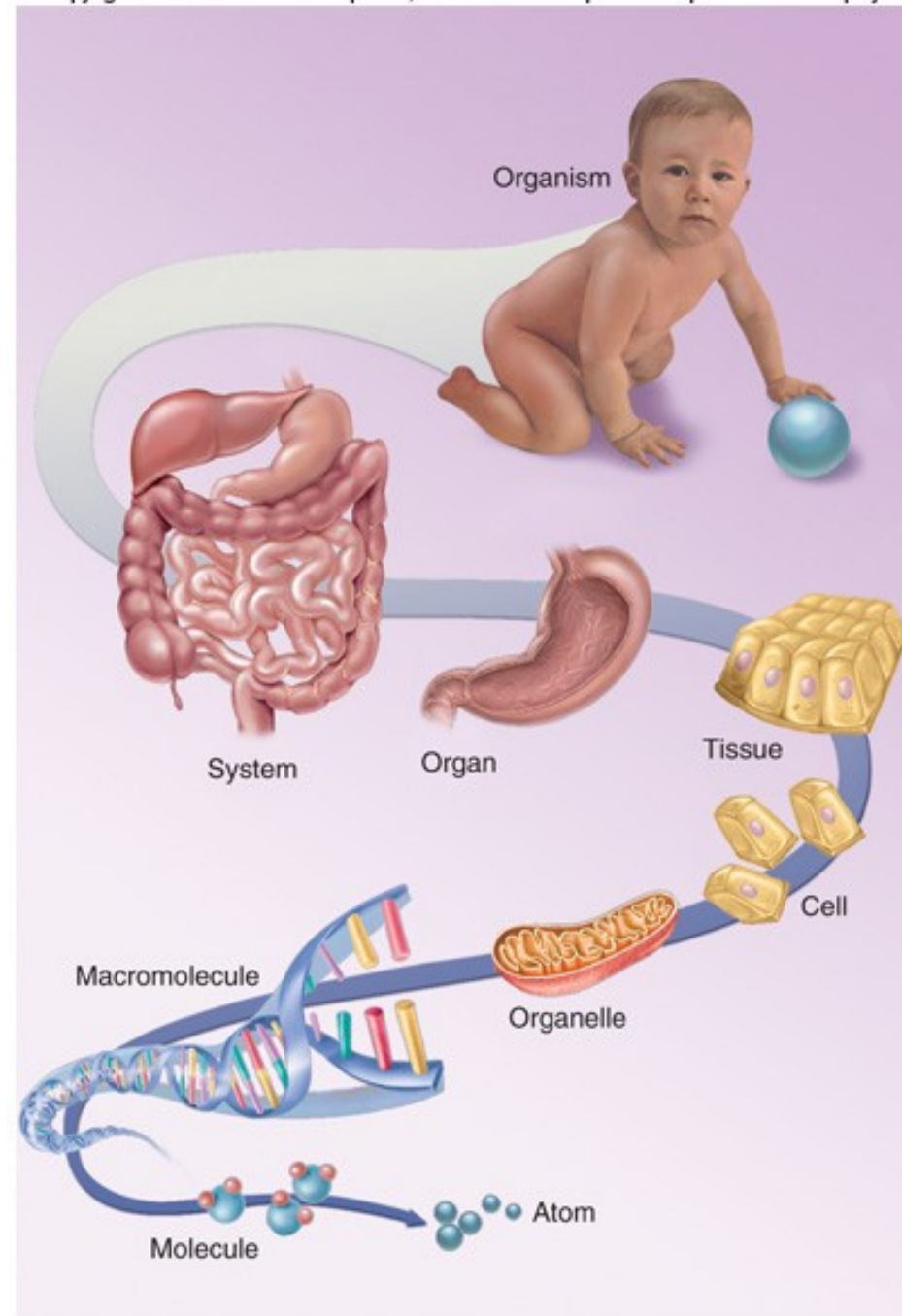
Learning Outcomes

- Describe the **general structure of an amino acid** and the formation and breakage of **peptide bond**.
- Describe the **components of a nucleotide** and identify their molecular structures.
- Describe **the structure** and composition of **nucleic acids** (DNA and RNA), and discuss the importance of base pairing and hydrogen bonding.

Rearrange these in the
correct order:



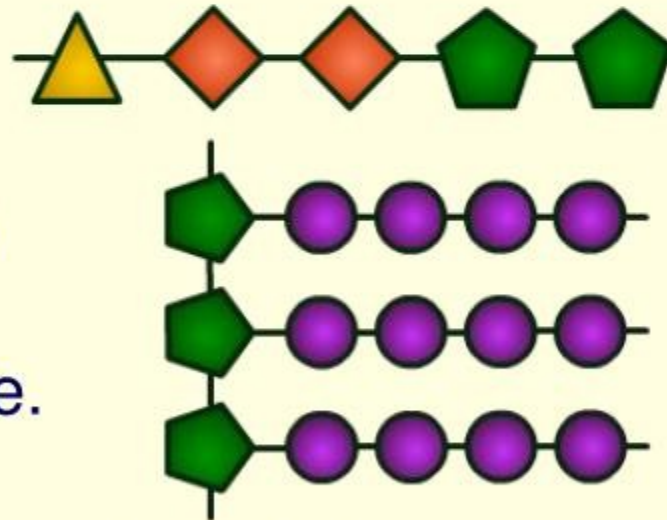
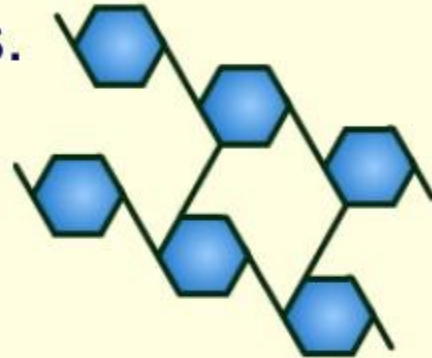
- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.
- 8.



What molecules are foods made of?

There are three main types of food molecules.

- **Carbohydrates** are chains of repeating molecules of glucose and other sugars.
- **Proteins** are chains of different amino acids.
- **Fats** are made up of lipids. A lipid has a structure of three fatty acid molecules and a glycerol molecule.



Food also contains vitamins and minerals, which are needed in small amounts for a healthy body.

- ❖ Biological molecules are often referred to as the molecules of life (bio-molecules) that are basically found in a living cell
- ❖ Required by living things to build body parts and maintain the biochemical processes required for life functions
- ❖ They categorized as **organic** and **inorganic** molecules in general.

Organic includes

- Carbohydrate
- Proteins
- Lipids
- Nucleic Acids

Inorganic- includes - Water and Minerals

Carbohydrates

❖ **Carbohydrate** molecule is made of atoms of **carbon, hydrogen** and **oxygen**.

- Important source of energy and help with communication between cells (cell-cell recognition).
- A convenient form in which to store chemical energy
 - ✓ starch in plants
 - ✓ glycogen in animals

Cont'd

- They also provide structural support for cells
 - ✓ cellulose, which is the main constituent of the primary cell wall of plants
 - ✓ chitin, which occurs in the cell walls of fungi and in the exoskeletons of insects
 - ✓ peptidoglycan, which occurs in bacterial cell walls

❖ They are found in the form of **either as a sugar or many sugars linked together**, called **saccharides**.

❖ Based on the number of sugar units they contain, they are categorized into three: **Monosaccharides, Disaccharides and Polysaccharides**

Carbohydrates

Carbohydrates are compounds of Carbon, Hydrogen and Oxygen. They are the source of energy in all living things and can add strength and support to cell membranes & cell walls.

Monosaccharides (M/S)

- (or Simple sugars)
- All carbohydrates are made of sugar molecules.
- A single sugar molecule is called a monosaccharide
- *E.g. Glucose, Fructose, Ribose*

Disaccharides (D/S)

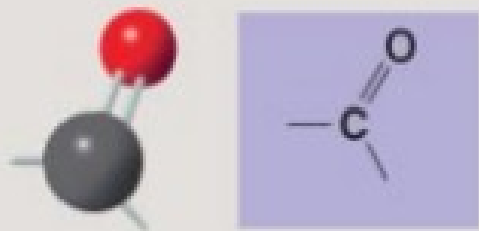
- Formed when two M/S join together
- Occurs during a **CONDENSATION REACTION** – where a water molecule is released
- The link between the two sugar molecules is called a GLYCOSIDIC BOND.
- *E.g. Sucrose, Maltose, Lactose*

Polysaccharides (P/S)

- Made up of hundreds of M/S joined together
- Long chains of M/S are joined by glycosidic bonds
- P/S can be branched or unbranched.
- *E.g. Starch, Cellulose, Glycogen*

Cont'd

- **Monosaccharides:** simple sugars with multiple OH groups. Based on the number of carbons they contain (3, 4, 5, 6), a monosaccharide is classified as a **triose**, **tetrose**, **pentose** or **hexose**.
- Based on the functional group that they possess **monosaccharides** can be classified as
 - ✓ Those with **aldehyde group** (CHO) are classified as **aldoses**, and
 - ✓ Those with a **ketone group** (C=O) are classified as **ketoses**.
- Fructose, glucose and galactose are all hexoses.



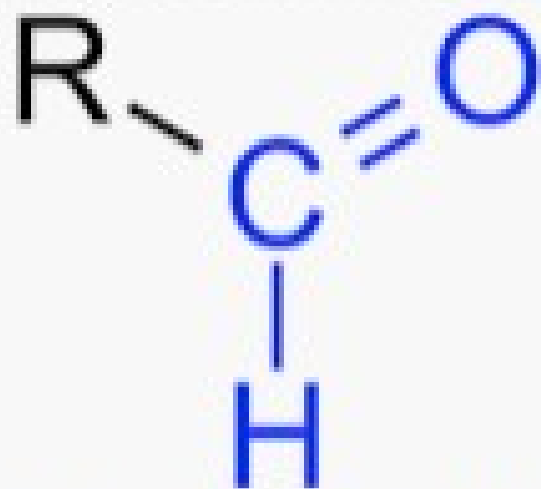
The carbonyl group (>CO) consists of a carbon atom joined to an oxygen atom by a double bond.

Ketones if the carbonyl group is **within a carbon skeleton**

Aldehydes if the carbonyl group is at the **end of the carbon skeleton**

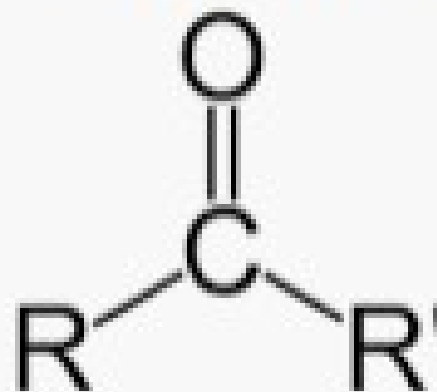
	Trioses ($\text{C}_3\text{H}_6\text{O}_3$)	Pentoses ($\text{C}_5\text{H}_{10}\text{O}_5$)	Hexoses ($\text{C}_6\text{H}_{12}\text{O}_6$)	
Aldoses	Glyceraldehyde	Ribose	Glucose	Galactose
Ketoses	Dihydroxyacetone	Ribulose	Fructose	

Aldehyde Functional Group



R is a hydrocarbon group that is attached to C=O

Ketone Functional Group



R and R' are hydrocarbon groups that are attached to C=O

2. Disaccharides: two monosaccharides covalently linked

- Oligosaccharides - a few monosaccharides covalently linked.
- Monosaccharides are rare in nature. Most sugars found in nature are disaccharides.
- Disaccharides are soluble in water, but they are too big to pass through the cell membrane by diffusion.

Disaccharides (D/S)

Examples of Disaccharides

Sucrose: glucose + fructose,

Lactose: glucose + galactose,

Maltose: glucose + glucose.

Sucrose is used in many plants for transporting food reserves, often from the leaves to other parts of the plant.

Lactose is the sugar found in the milk of mammals and maltose is the first product of starch digestion and is further broken down to glucose before absorption in the human gut.

Cont'd

- ✓ They are broken down in the small intestine during digestion to give the smaller monosaccharides that pass into the blood and through cell membranes into cells.



- ✓ **Hydrolysis reaction** is the reverse of a condensation reaction and it releases energy.

Cont'd

❑ **Condensation** is reaction in which two molecules are combine in the presence of catalyst with elimination of water.

A **condensation reaction** takes place by releasing water.

- This process requires energy. A glycosidic bond forms and holds the two monosaccharide units together.
- ✓ The three most important disaccharides are **sucrose**, **lactose** and **maltose**. Sucrose is a non-reducing sugar.
 - **Lactose** and **maltose** are reducing sugars.

Cont'd

- Example of disacharrides:
 - ✓ α -glucose + α -glucose $\Rightarrow$ Maltose (disaccharide)
 - ✓ β -glucose + β -galactose $\Rightarrow$ Lactose (disaccharide)
 - ✓ α -glucose + fructose $\Rightarrow$ Sucrose (disaccharide)

Cont'd

- ✓ Monosaccharides are used very quickly by cells. However, a cell may not need all the energy immediately and it may need to store it.
- ✓ **Monosaccharides are converted into disaccharides in the cell by condensation reactions.** Further condensation reactions result in the formation of polysaccharides.
- ✓ These are broken down by hydrolysis into monosaccharides when energy is needed by the cell

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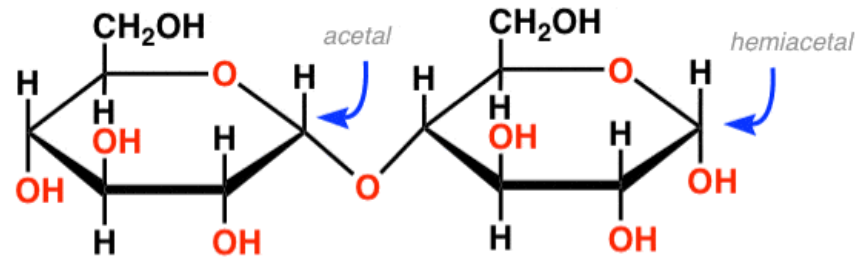
▪ Reducing sugar vs non-reducing sugar

- A reducing sugar is any sugar that is capable of acting as a **reducing agent** (chemical species w/c donates electron to electron recipient).
- Monossacharides are reducing sugars

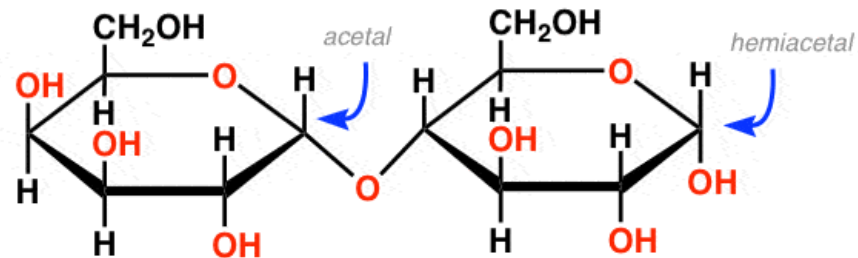
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Lactose and Maltose are also reducing sugars and give a positive Benedict test

Maltose:

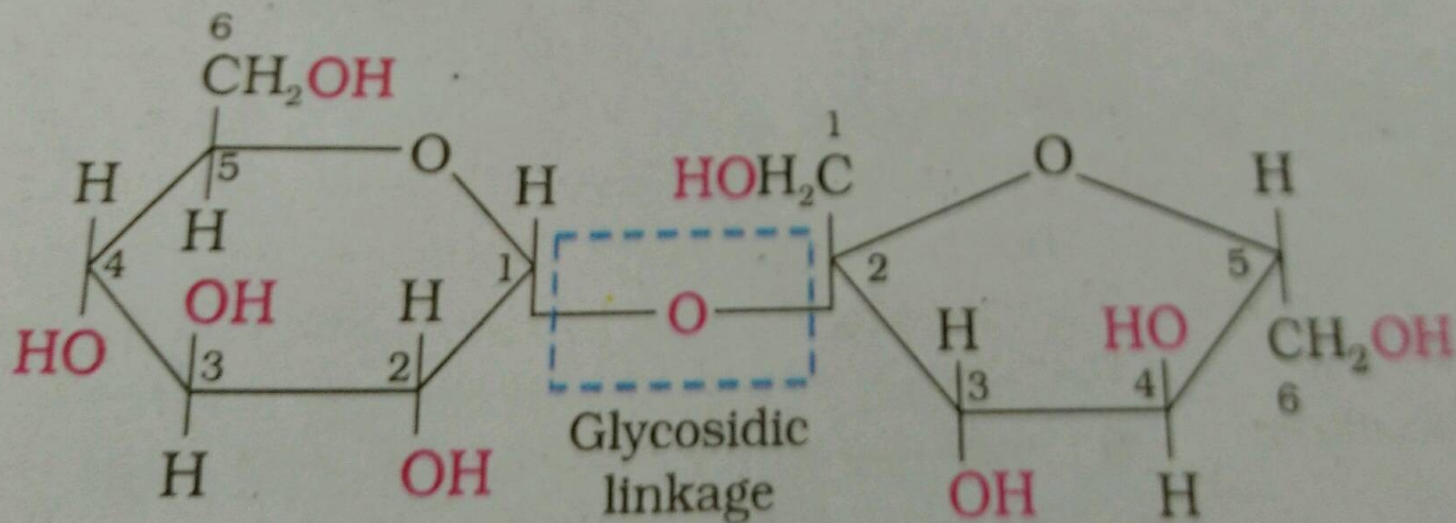


Lactose:



Cont'd

These two monosaccharides are held together by a glycosidic linkage between C1 of α -glucose and C2 of β -fructose. Since the reducing groups of glucose and fructose are involved in glycosidic bond formation, sucrose is a non reducing sugar.



α -D-Glucose

β -D-Fructose

Sucrose

Polysaccharides

- ❖ **Polysaccharides** - polymers consisting of chains of monosaccharide or disaccharide.
- ❖ Their molecules are built as many hundreds of monosaccharide molecules join together by forming condensation links.
- ❖ Monosaccharides can undergo a series of **condensation reactions**, adding one unit after another to the chain until very large molecules (polysaccharides) are formed.
- ❖ This is called **condensation polymerization**, and the building blocks are called **monomers**. **E.g. Starch, Glycogen, Celullose.**

Polysaccharides

Poly-saccharide:	Function:	Structure:	Relationship of structure to function:
Starch	Main storage polysaccharide in plants.	Made of 2 polymers - amylose and amylopectin. <i>Amylose</i>: a long <u>unbranched chain</u> of alpha-glucose. The angles of the glycosidic bonds give it a <u>coiled structure</u> (also called a helix) <i>Amylopectin</i>: a long <u>branched chain</u> of alpha-glucose. Its <u>side branches</u> make it particularly good for the storage of glucose.	Insoluble therefore good for storage. Helix is <u>compact</u> and <u>good</u> for <u>storage</u>. The branches mean that the <u>enzymes</u> can <u>get to</u> the glycosidic <u>bonds easily</u> to break them & release the glucose.
Glycogen	Main storage polysaccharide in animals and fungi	Similar to amylopectin but with <u>many more branches</u> which are also shorter.	The number and length of the <u>branches</u> means that it is extremely compact and very fast hydrolysis.
Cellulose	Main structural component of plant cell walls	Adjacent chains of long, unbranched polymers of glucose joined by β -1,4-glycosidic bonds hydrogen bond with each other to form microfibrils.	The microfibrils are strong and so are structurally important in plant cell walls.

Cont'd

❖ **Starch**: storage energy in plants. It exists in two forms (**amylose** and **amylopectin**).

- **Amylose** is a linear (unbranched) molecule containing many hundreds of α -glucose molecules joined by α -1,4-glycosidic bonds.
- ✓ coil into a helical structure

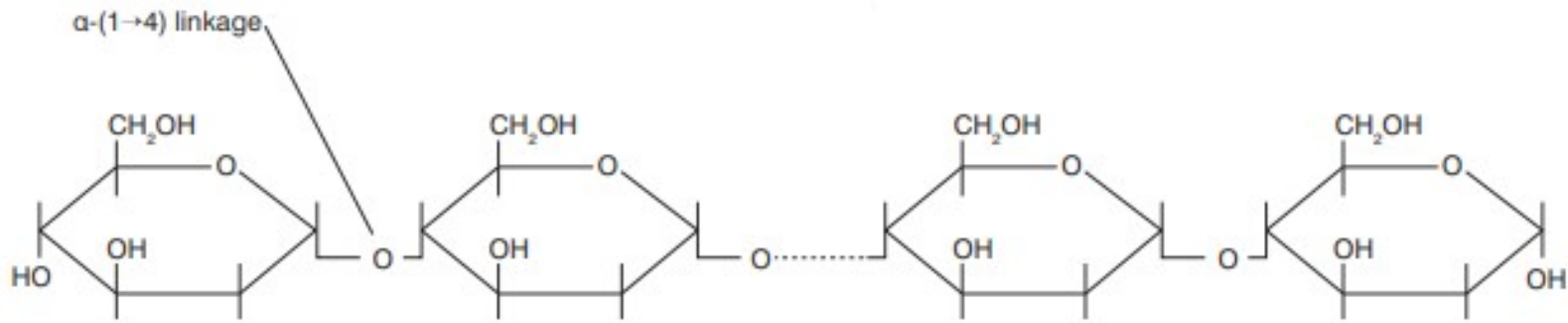


Figure 2.23 Linkages in amylose

Cont'd

❖ **Starch**: storage energy in plants. It exists in two forms (**amylose** and **amylopectin**).

- **Amylopectin**- also has a linear 'backbone' of α -glucose molecules joined by α -1,4-glycosidic bonds. But in **amylopectin**, there are also side branches. These occur at certain points along the chain when a glucose molecule forms an α -1,6-glycosidic bond with another glucose molecule as well as the usual α -1,4-glycosidic bond. This results in amylopectin having a branching structure.

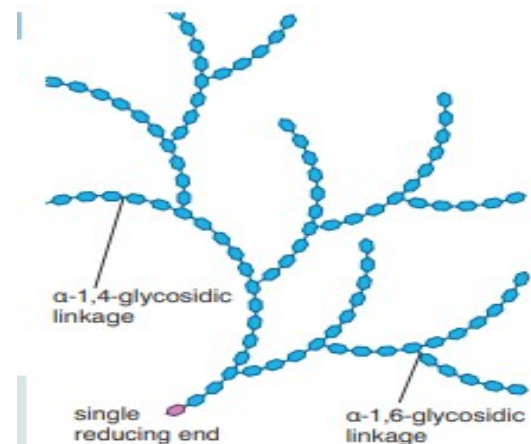
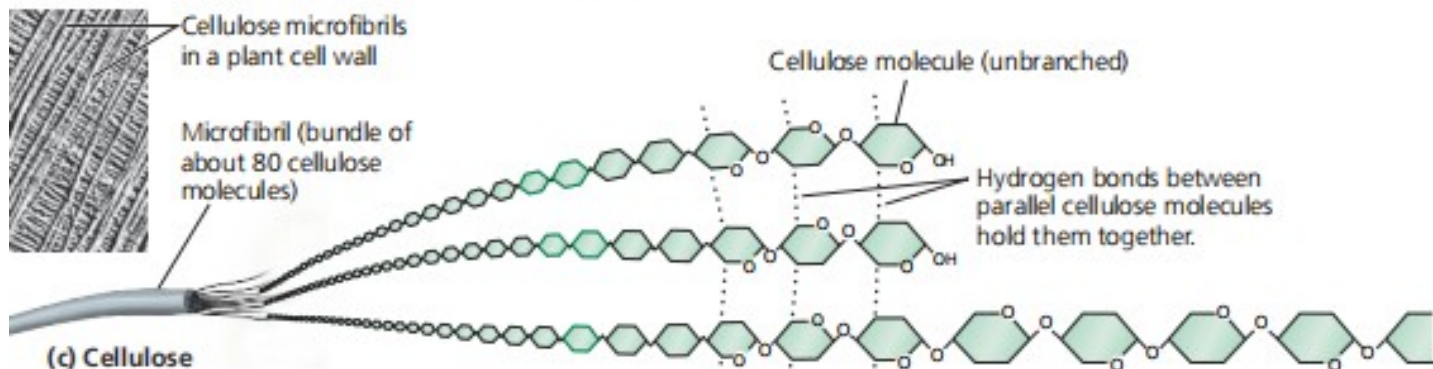
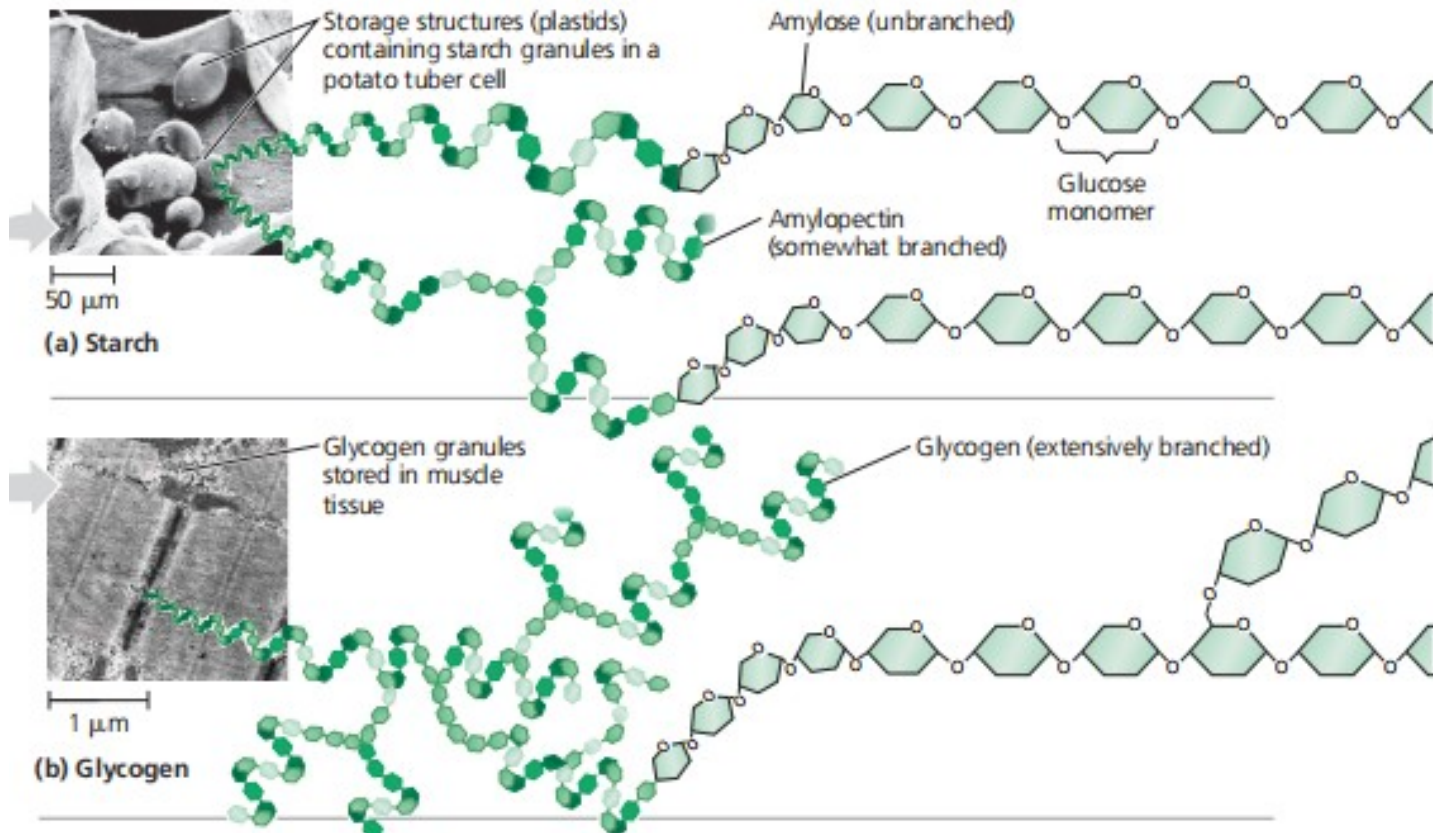


Figure 2.25 The structure of amylopectin

Cont'd

- ❖ **Glycogen**: is amylopectin with very short distances between the branching side-chains
 - It has a similar structure to that of amylopectin but there are more α -1,6 links, making it much more highly branched.
 - Starch from plants is hydrolysed in the body to produce glucose
 - Glucose passes into the cell and is used in metabolism. Inside the cell, glucose can be polymerized to make **glycogen** which acts as a **carbohydrate energy store in animal cell**.
- ❖ **Cellulose**: a polymer made from β -glucose molecules joined by β -1,4- glycosidic bonds, and the polymer molecules are 'straight'.
 - Make up the cell wall of plants



Lipids

- ❖ Nearly all lipids contain only the elements carbon, hydrogen and oxygen, but they contain much less oxygen than carbohydrates.
- ❖ Lipids are a highly variable group of molecules that include **fats, oils, phospholipids, waxes** and some steroids.
 - **triglycerides** – formed from glycerol and three fatty acids.
 - **phospholipids** – formed from glycerol, two fatty acids and a phosphate group
 - **waxes** – formed from fatty acids and long-chain alcohols
 - ✓ Waxes are so insoluble in water that they make excellent water repellents, for example, in coating birds' feathers and the epidermis of the leaves of plants (the waxy cuticle).

Cont'd

- ❖ They are esters of **fatty acids** and **alcohol** (glycerol or chains of alcohols).
- ❖ Lipids are water-insoluble molecules that are soluble in organic solvents.
- ❖ Fatty acids are made mostly from chains of **carbon** and **hydrogen** and they bond to a range of other types of atoms to form many different lipids.

Lipids cont'd

- ❖ The primary function of lipids is to **store energy**.
- ❖ A lipid called a triglyceride is a fat if it is solid at room temperature and oil if it is liquid at room temperature.
 - ✓ **Fats:** consists of a glycerol molecule joined to three fatty acids
 - ✓ **Phospholipid:-** has only two fatty acids attached to glycerol

Lipids cont'd

❖ Saturated and unsaturated fatty acids

- **Saturated fatty acids:** there are no double bonds between carbon atoms composing a chain, then as many hydrogen atoms as possible are bonded to the carbon skeleton.
 - ✓ lack double bonds and their flexibility allows the fat molecules to pack together tightly.

Eg. lard and butter w/c solid at room temperature

- **Unsaturated fatty acids:** has one or more double bonds, with one fewer hydrogen atom on each double-bonded carbon.

Eg. Fish and plant fats w/c is liquid at room temperature

Cont'd

❑ Various types of lipids occur in the human body, namely:

1) triacylglycerol,

2) cholesterol, and

3) polar lipids, which include phospholipids, glycolipids and sphingolipids.

Properties of lipids

- Insoluble in water
- Longer chains
 - ✓ more hydrophobic, less soluble
- Double bonds increase solubility

Cont'd

■ Melting points:

- ✓ Depend on chain length and saturation
- ✓ Double bonds lead acyl chain disorder and low melting temperatures
- ✓ Unsaturated fatty acids are liquid at room temperature.

Importance of lipids

- As the main component of cell membranes (phospholipids)
- Insulation of heat and water,
- Storing energy, protection and cellular communication.

Functions of Lipids

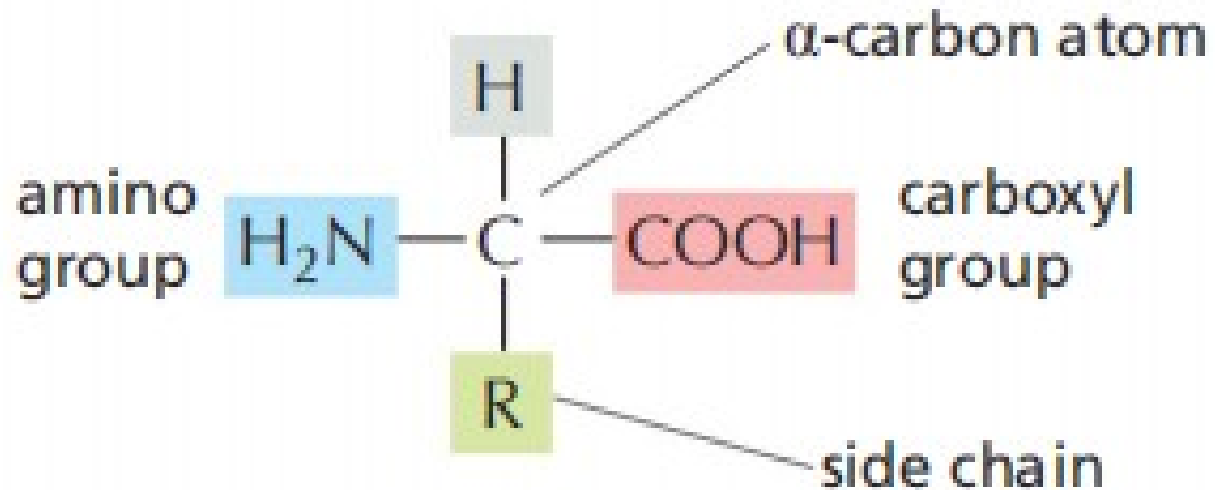
1. **High-energy store** - they have a high proportion of H atoms relative to O atoms and so yield almost twice as much energy than the same mass of carbohydrate.
2. **Thermal insulation** - fat conducts heat very slowly so having a layer under the skin (adipose tissue) keeps metabolic heat in.
3. **Shock absorption** – acts as a cushion against blows (to organs)
4. **Buoyancy** - as lipids float on water, they can have a role in maintaining buoyancy in organisms.
5. **Storage** - lipids are non-polar and so are insoluble in water, so can be stored/localised in animals.
6. **Production of water** - some water is produced as a final result of respiration.
7. **Electrical insulation** - the myelin sheath around axons prevents ion leakage.
8. **Waterproofing** - waxy cuticles are useful, for example, to prevent excess evaporation from the surface of a leaf.
9. **Hormone production** - steroid hormones. Oestrogen requires lipids for its formation, as do other substances such as plant growth hormones.

C. Proteins

- ❖ A protein is a compound made of amino acids.
- ❖ Protein is a biologically functional molecule made up of one or more polypeptides
- ❖ Amino acids are small compounds that are made of **carbon**, **nitrogen**, **oxygen**, **hydrogen**, and sometimes sulfur.
- ❖ All amino acids share the same general structure.
- ❖ Amino acids have a central carbon atom and other bonds like amino group ($-\text{NH}_2$), a carboxyl group ($-\text{COOH}$), and a variable group ($-\text{R}$).

C. Proteins

The general formula of an amino acid is



R is commonly one of 20 different side chains.

Fig. Basic structure of amino acid

Proteins cont'd

- The common amino acids are grouped according to whether their side chains are: acidic, basic, uncharged polar or nonpolar
- In proteins, amino acids are commonly joined together by an **amide linkage**, called a **peptide bond**.
- Proteins are long polymers of amino acids linked by peptide bonds.
- Function in defense, storage, transport, cellular communication, movement, or structural support.

Enzymatic proteins

Function: Selective acceleration of chemical reactions

Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.



Storage proteins

Function: Storage of amino acids

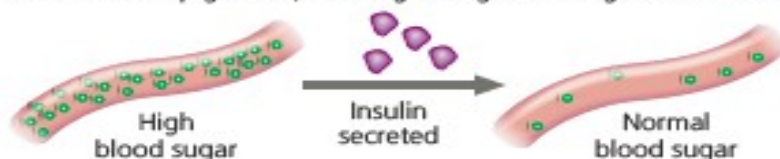
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.



Hormonal proteins

Function: Coordination of an organism's activities

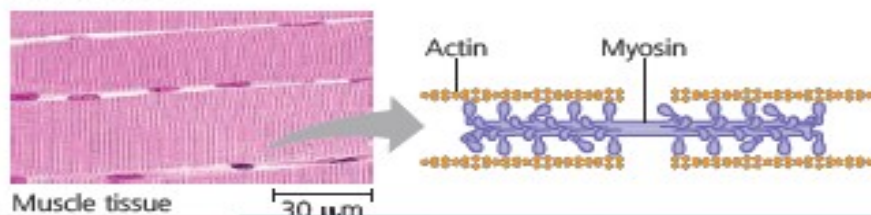
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.



Contractile and motor proteins

Function: Movement

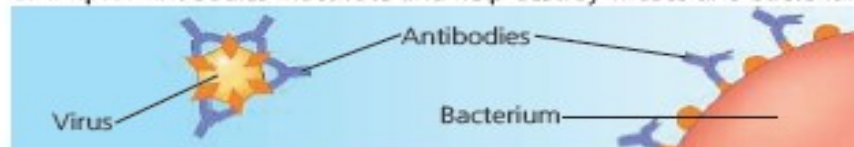
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.



Defensive proteins

Function: Protection against disease

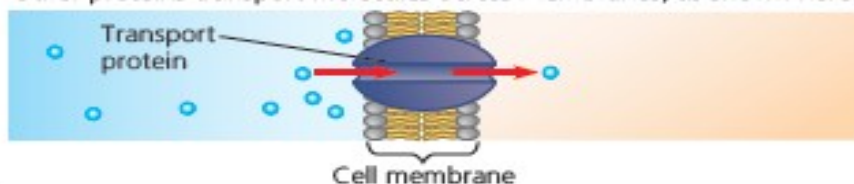
Example: Antibodies inactivate and help destroy viruses and bacteria.



Transport proteins

Function: Transport of substances

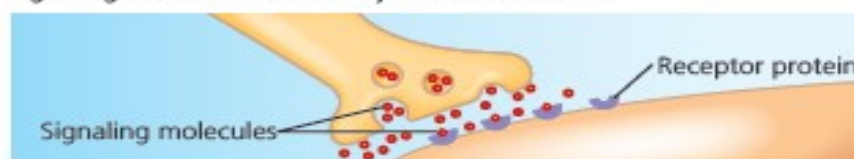
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.



Receptor proteins

Function: Response of cell to chemical stimuli

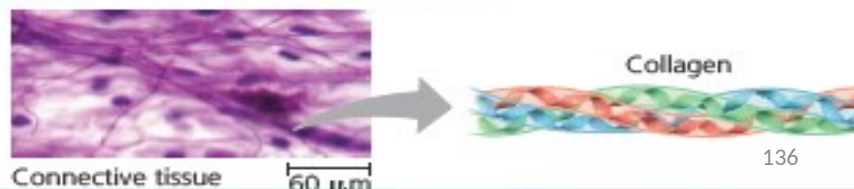
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



Structural proteins

Function: Support

Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.

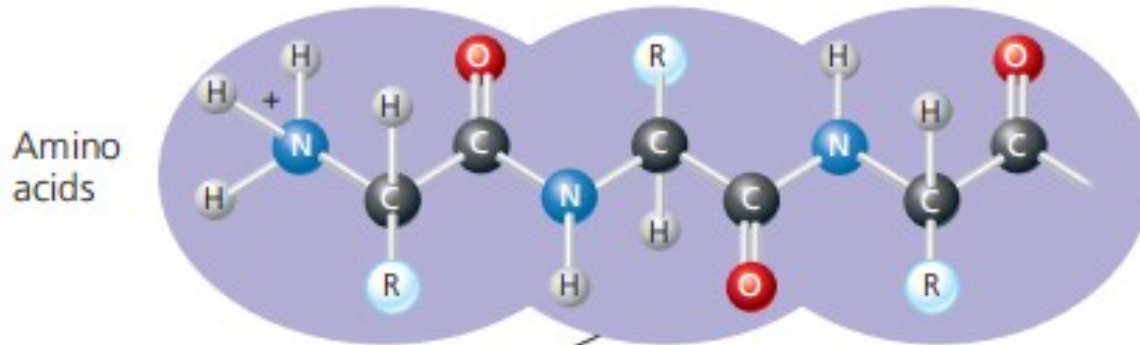


Proteins cont'd

- ❖ The variable group makes each amino acid different. There are 20 different variable groups, and proteins are made of different combinations of all 20 different amino acids.
- ❖ Several covalent bonds called peptide bonds join amino acids together to form proteins
- ❖ A **peptide bond** forms between the **amino group** of one amino acid and the **carboxyl** group of another.

Proteins cont'd

- These peptides always drawn and named beginning with the **amino terminus** and ending with the **carboxy** terminus
- Structure of protein can be described at four levels of complexity
- **Primary structure**- defined by number the of amino acids in a chain and the order in which the amino acids are joined.
 - ✓ Linear sequence of amino acids with in a protein



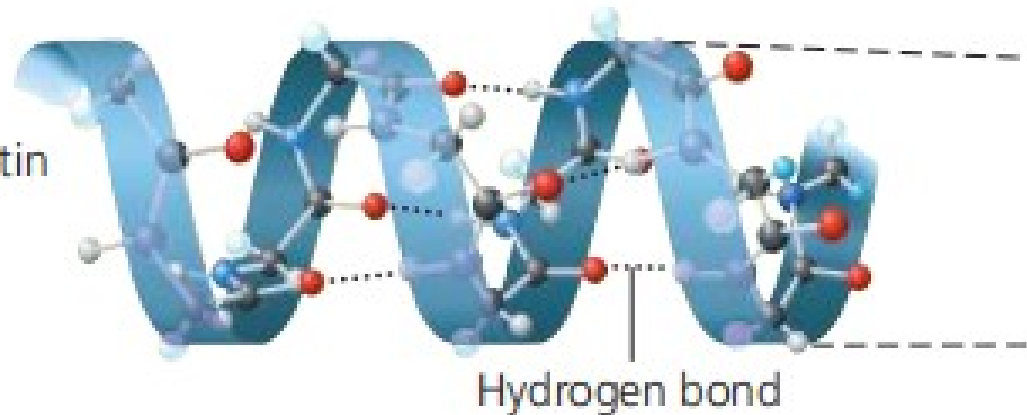
Proteins cont'd

- ❑ Secondary structure- as the peptide grows longer, the chain begins to bend.
- ✓ When the amino group of one section on the peptide moves close to the carbonyl group of an other section, intermolecular bond called hydrogen bond develop.
- ✓ This intermolecular bond bend the linear section and giving two common types of secondary structure (*α _helix and β _pleated sheets*)

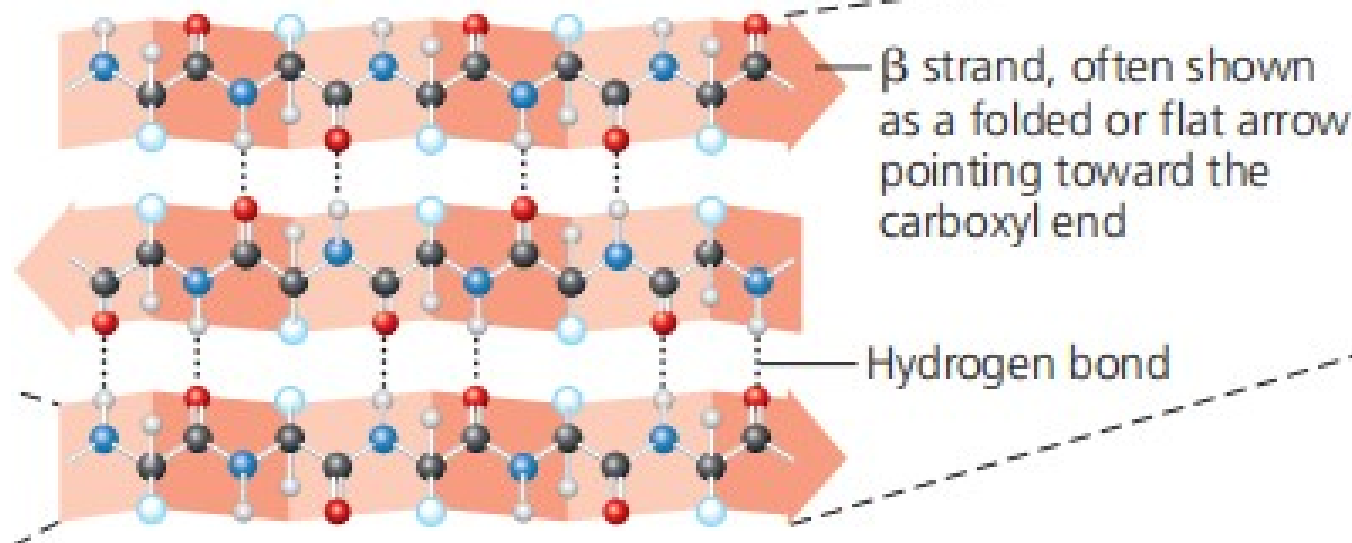
Secondary structure cont'd

- *α _helix*: helical pattern is a result of hydrogen bonds between the coils of helix
- *β _pleated sheets*:- hydrogen bond holds the peptide chain in parallel manner
- amino acid sequence the folding and intramolecular bonding of the linear amino acid w/c determines proteins **unique three dimensional shape** such as helices, pleats, and folds

A region of **α helix** in transthyretin



A region of **β pleated sheet** (made up of adjacent β strands) in transthyretin



Proteins cont'd

- **Tertiary structure**- ensemble of formations and folds in single linear chains of amino acids (polypeptide) constitute tertiary structure
 - three dimensional shape which is formed
 - Several important bonds help to create tertiary structure
 - ✓ disulfide bridge, van der waals force, hydrogen bonds, hydrophobic interaction
 - tertiary structure of many proteins is globular, eg. hemoglobin while some proteins form long fibers

Proteins cont'd

- **Quaternary structure**- formed when two or more peptide chains join together via electrostatic forces
 - ✓ macromolecules with multiple polypeptide subunits
 - ✓ arises when a protein consists of two or more polypeptide chains
 - ✓ Eg. hemoglobin

Quaternary structure cont'd

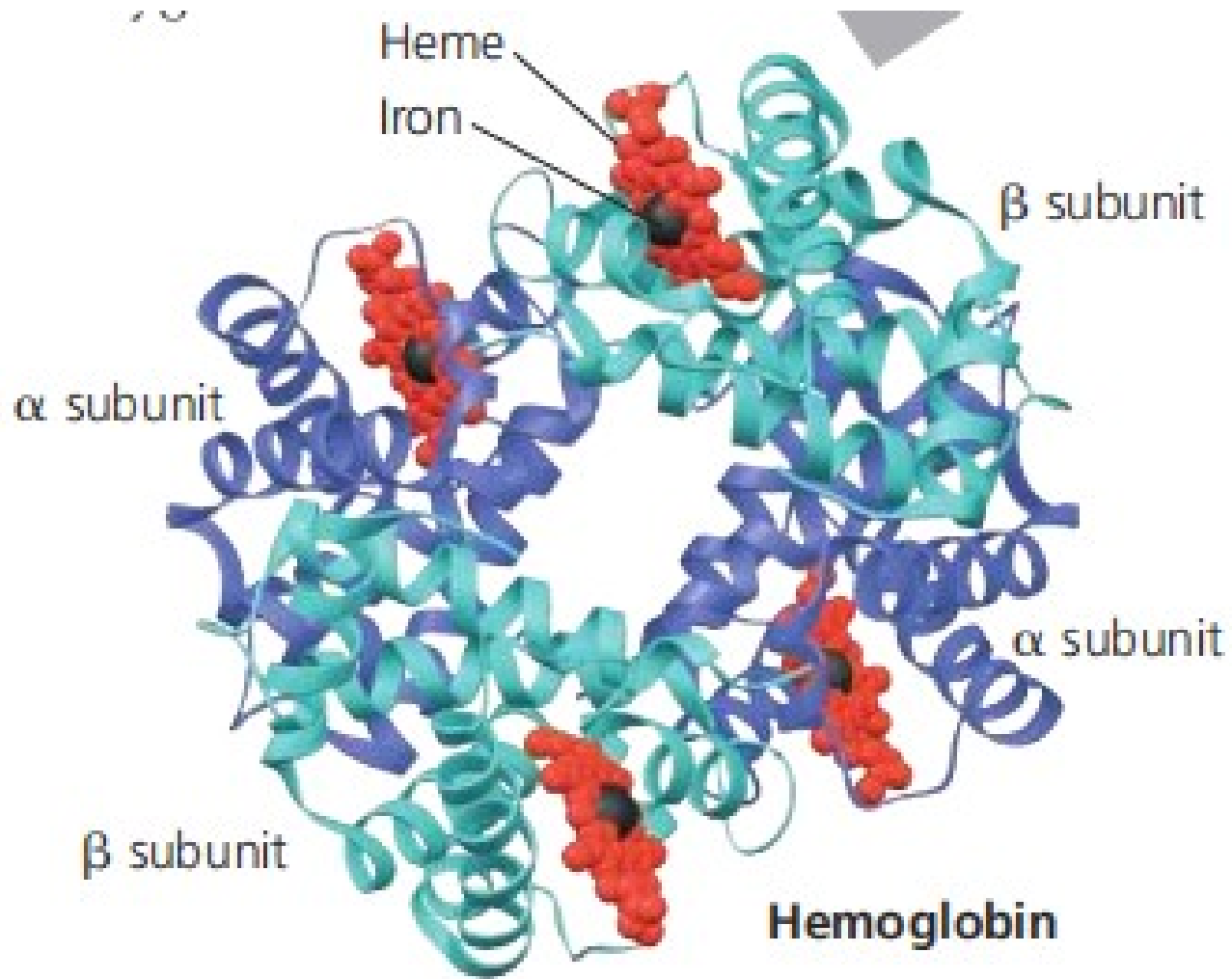


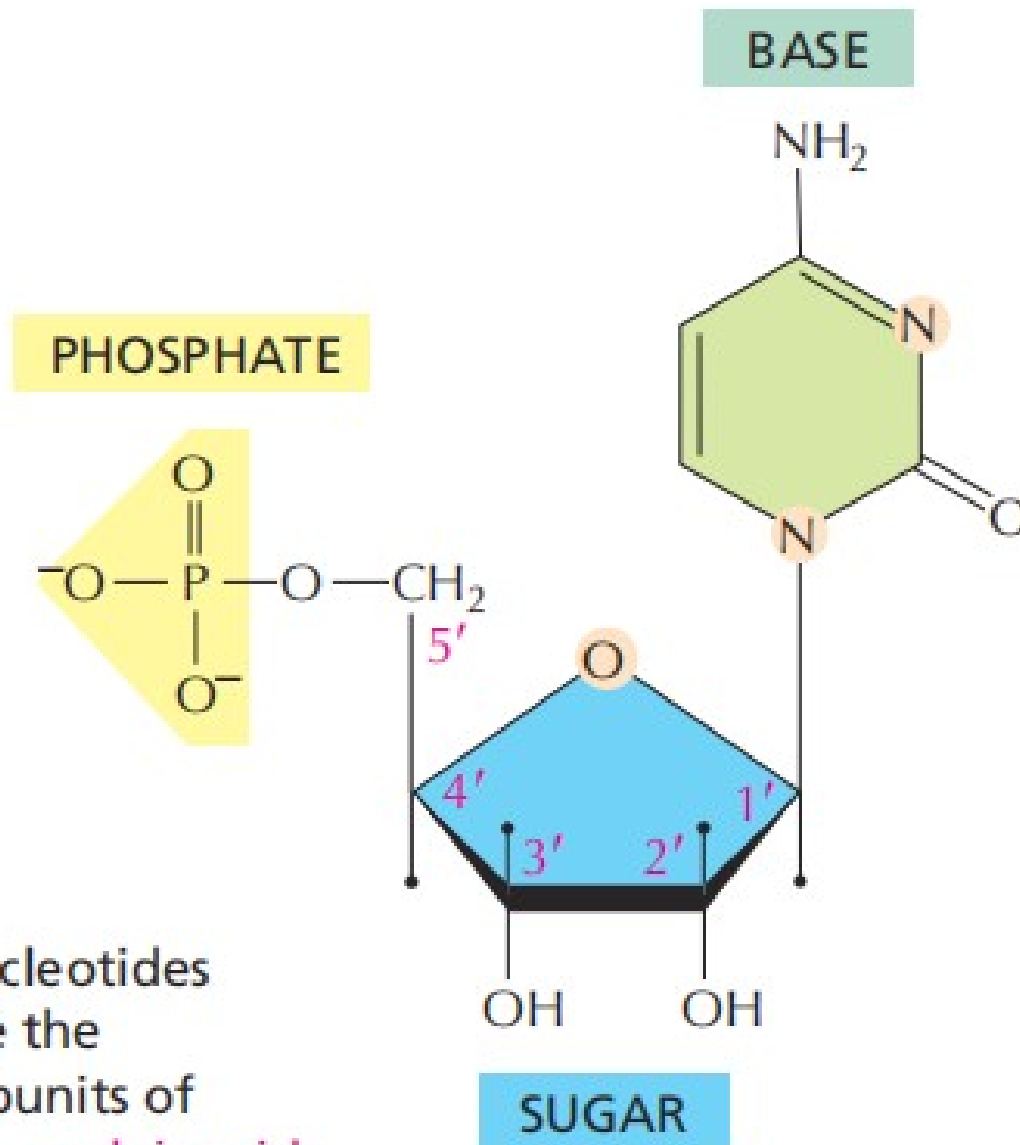
Table 5.1 An Overview of Protein Functions

Type of Protein	Function	Examples
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes
Structural proteins	Support	Silk fibers; collagen and elastin in animal connective tissues; keratin in hair, horns, feathers, and other skin appendages
Storage proteins	Storage of amino acids	Ovalbumin in egg white; casein, the protein of milk; storage proteins in plant seeds
Transport proteins	Transport of other substances	Hemoglobin, transport proteins
Hormonal proteins	Coordination of an organism's activities	Insulin, a hormone secreted by the pancreas
Receptor proteins	Response of cell to chemical stimuli	Receptors in nerve cell membranes
Contractile and motor proteins	Movement	Actin and myosin in muscles, proteins in cilia and flagella
Defensive proteins	Protection against disease	Antibodies combat bacteria and viruses.

D. Nucleic acids

- **Nucleic acids** are complex macromolecules that **store** and **transmit genetic information**.
- Are made up of smaller repeating subunits called **nucleotides**.
- Nucleotides are composed of **carbon, nitrogen, oxygen, phosphorus, and hydrogen atoms**.
- There are two types of nucleic acids in living organisms: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

Cont



Nucleotides
are the
subunits of
the **nucleic acids**.

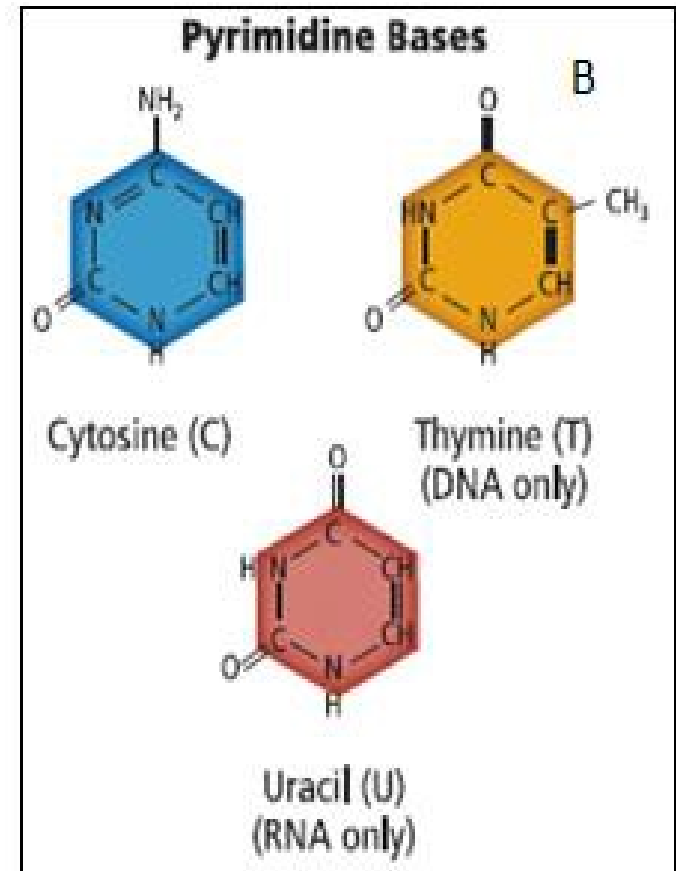
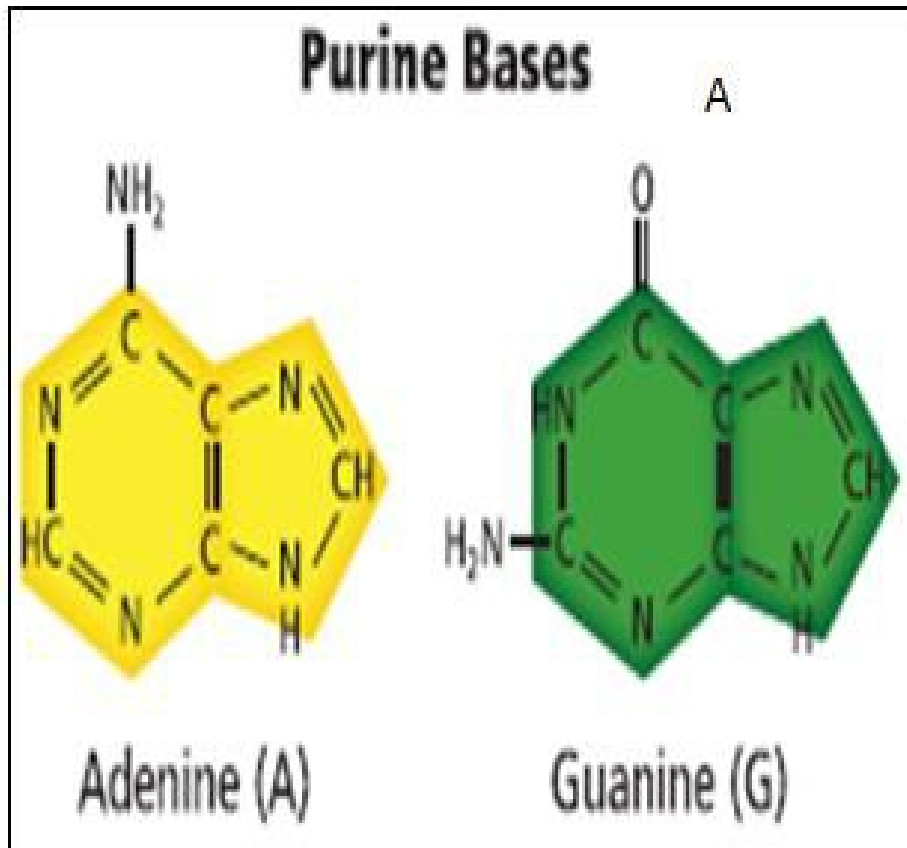


Fig: Nitrogenous bases

E. Vitamins

- **Vitamins** are organic compounds that are needed in small amounts for metabolic activities.
- Are organic components of food found in very small amount in many different foods
- Many vitamins help enzymes function well. Vitamin D is made by cells in your skin.
- Some B vitamins and vitamin K are produced by bacteria living in the large intestine.

Vitamins cont'd

On the bases of their solubility vitamins are classified as **fat soluble vitamins** and **water soluble vitamins**

❑ **Fat soluble vitamins:** are vitamins that dissolve in fat

- ✓ They are stored within our fat and can be saved for later use
- ✓ E.g. Fat soluble vitamins are: **A, D, E and K**

❑ **Water soluble vitamins:** vitamins that are dissolve in water

- ✓ Since our body is watery environment, these vitamins are move through our body easily and can be flashed out by the kidney
- ✓ E.g. **Vitamin B complex and Vitamin C**

Characteristics of Vitamins

- Are required in small quantities in the diet
- Water soluble vitamins can not be stored in human tissue, their excess is excreted with urine
- Fat soluble vitamins can be stored in adipose tissue and the liver
- Essential nutrients for the healthy maintenance of the cell, tissue and organs

UNIT 3. CELL BIOLOGY

- **3.1. Cell theory**
- **3.2. Types of cell**
- **3.3. Parts of the cell and its function**
- **3.4. Cellular respiration**

3.1. Cell Theory

By the end of this section you should be able to:

- Tell the history of cell biology.
- Describe cell theory and investigate the size, structure and shape of cells.
- State the basic functions of cells.
- Appreciate that all life on Earth originates from cells.

- The development of instruments that extend the human senses allowed the discovery and early study of cells.
- Microscopes were invented in 1590 and further refined during the 1600s.
- Cell walls were first seen on dead cells of oak bark by Robert Hooke in 1665 and living cells by Antoni van Leeuwenhoek a few years later.
- Three important parameters in microscopy are
 - magnification, resolution, and contrast.

cont'd

- The light microscope cannot resolve detail finer than about 0.2 micrometer (μm), or 200 nanometers (nm), regardless of the magnification
- To see these structures in any detail required the development of a new instrument.
- In the 1950s, **the electron microscope** was introduced to Biology.
- Rather than focusing light, the electron microscope (EM) focuses a beam of electrons through the specimen or onto its surface

cont'd

- **Robert Hook** ⇒ the first to observe plant cells with a crude microscope (late 1600s)
- **Mathias Schleiden and Theodore Schwann** ⇒ all living things are composed of cells (1830s).
- **Rudolph Virchow** ⇒ cells arise only from other cells

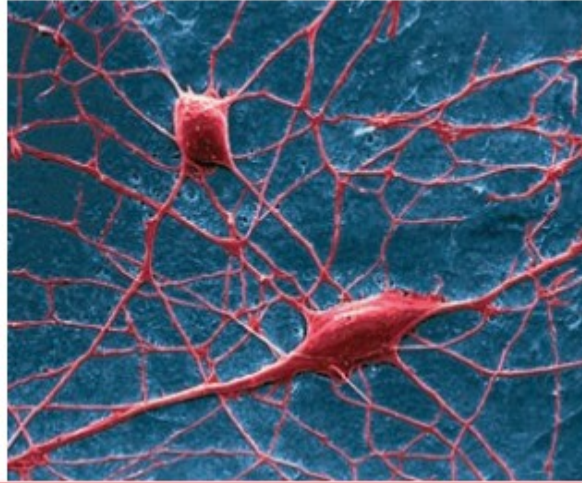
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- Billions of cells in the case of human beings, just one cell in the case of organisms like amoeba.

blood cells



nerve cells



muscle cells

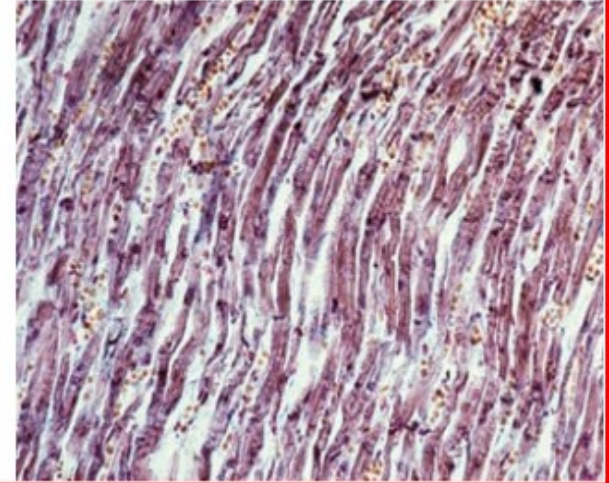


Figure 4.1 Some of the different cells in our bodies

There is only one cell in **amoeba** and in **vorticella**

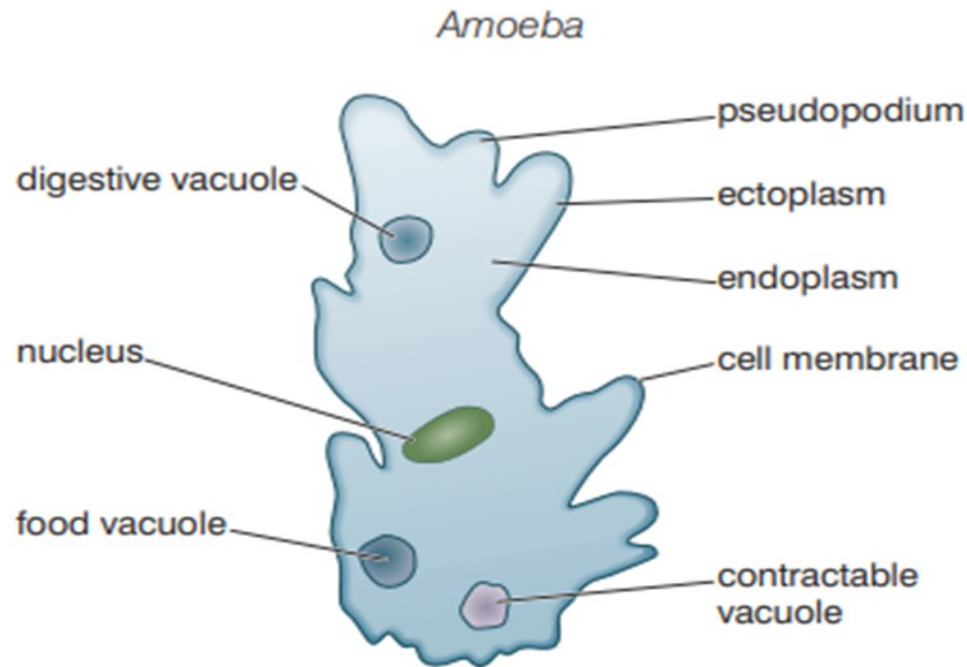


Figure 4.2 The unicellular organisms *Amoeba* and *Vorticella*

Cont'd

- The discovery of cell was after the development of reliable microscopes.
- Many biologists and other scientists contributed to the discovery of cells and the statement of the very first cell theory

A timeline for the development of the cell theory

Robert Hooke (1665)

- ✓ 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 than **30×** are very blurred and do not show much detail.
- ✓ Hooke saw only dead cells

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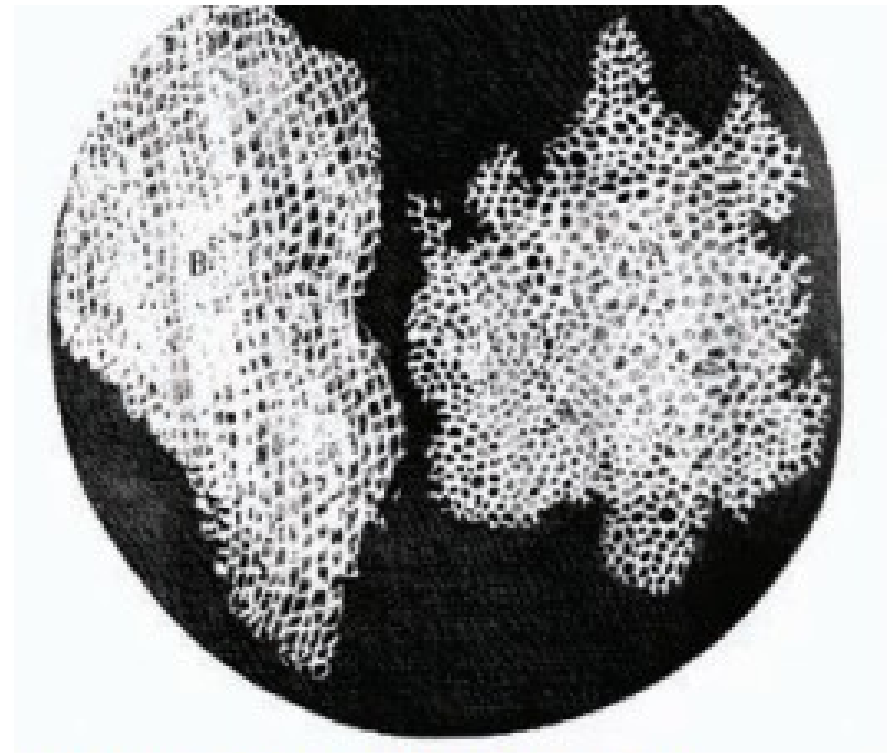


Figure 4.3 Robert Hooke's drawing of cells in cork

Figure 4.4 Robert Hooke's microscope

Cont'd

Anton van Leeuwenhoek (1674)

- ✓ sees living, moving unicellular organisms (protocists) in a drop of water.
- ✓ He used a simple microscope with only one lens.
- ✓ 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'.

Cont'd



Figure 4.6 Anton van Leeuwenhoek



Figure 4.5 Anton van Leeuwenhoek's microscope

Cont'd

About compound microscopes

A compound microscope is the sort of microscope we use in biology today. It has two lenses – the **eyepiece** and the **objective** lens (check back to unit 1 for more details) – that combine to produce the final image. Because two lenses are used, compound microscopes are capable of higher magnifications than simple microscopes, which use only one lens. The second lens (the eyepiece) magnifies the already magnified image produced by the objective lens. However, it also magnifies any 'aberrations' or faults in the image. So if the lenses are not well made, the final image, at high magnifications, will be blurred. **The first compound microscope was made in 1595 by the Dutch scientist, Zaccharias Jansen.**

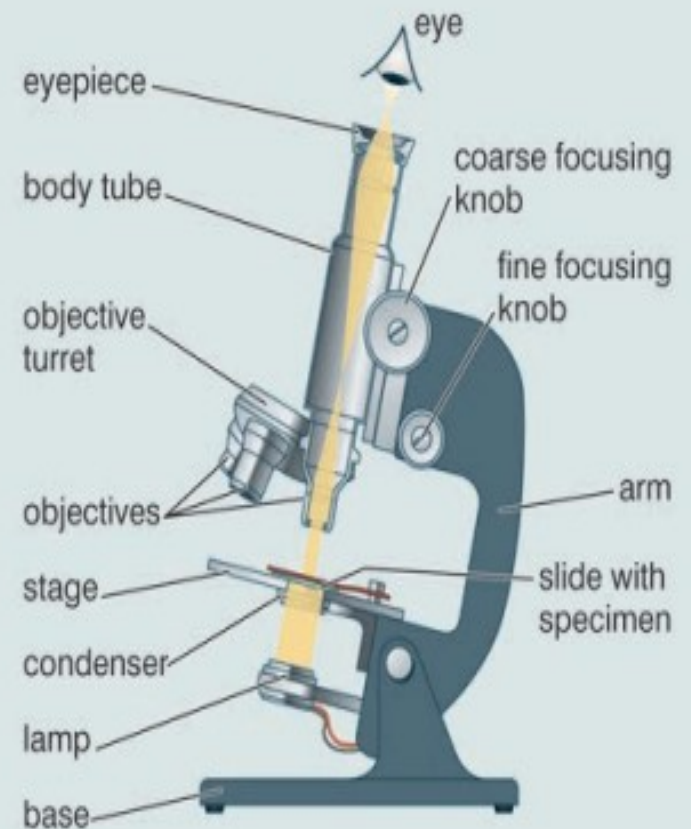


Figure 4.7 A modern compound microscope

Cont'd

Rene Dutrochet (1824)- French biologist

- concludes that all organisms are composed of cells.
- This follows many years work in which he also discovers:
 - ✓ the stomata in the epidermis of leaves
 - ✓ the process of osmosis
 - ✓ chlorophyll is needed for photosynthesis to occur
 - ✓ respiration occurs in both animals and plants
- He first states the **cell theory** by recognizing 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'.

Cont'd

Matthias Schleiden and Theodor Schwann (1839)

- Put forward the First clearly stated cell theory which states that:
 - ✓ the cell is the unit of structure, physiology and organization in living things
 - ✓ the cell retains a dual existence as:
 - a distinct entity, and
 - a 'building block' in the formation of organisms
 - ✓ cells form by free-cell formation (spontaneous generation)

Note: the final idea of spontaneous generation has now been proved false.

Cont'd

Rudolf Virchow (1858)

- A German doctor who develops many surgical techniques and promotes several fields of modern medicine. He declared:
- ✓ *'Omnis cellula e cellula'*, meaning **a cell can only arise from another cell like it.**

Cont'd

✓ With this Rudolf Virchow completes the first accepted version of the cell theory:

- all organisms are made up of one or more cells
- all cells come from pre-existing cells
- the cell is the unit of structure, physiology and organization in living things.
- 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:

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

Cont'd

Besides these major steps in the development of a cell theory, there have been other developments in the study of cell biology. Some of these are listed below.

Key events in the study of cell biology

Table 4.1 Key events in cell biology

	Event
1595	Jansen builds the first compound microscope.
1626	Redi postulates that living things do not arise from spontaneous generation.
1665	Hooke describes 'cells' in cork.
1674	Leeuwenhoek discovers protozoa.
1833	Brown describes the cell nucleus in cells of an orchid.
1839	Schleiden and Schwann propose a cell theory.
1857	Kolliker describes mitochondria.
1858	Virchow states <i>omnis cellula e cellula</i> .
1869	Miescher isolates DNA.
1879	Fleming describes chromosome behaviour during mitosis.
1898	Golgi describes the Golgi apparatus in cells.
1939	The first transmission electron microscope.
1953	Watson and Crick propose the double-helix structure of DNA.
1965	The first scanning electron microscope.
2000	Human genome DNA sequence draft.

How big are cells?

- It depends on the type of the cell
 - ✓ E.g. a **chicken's egg** is a pretty big cell, up to **5 cm** in length
 - ✓ On the other hand, the **smallest bacterial cells** are only just over **100 nm** in length.

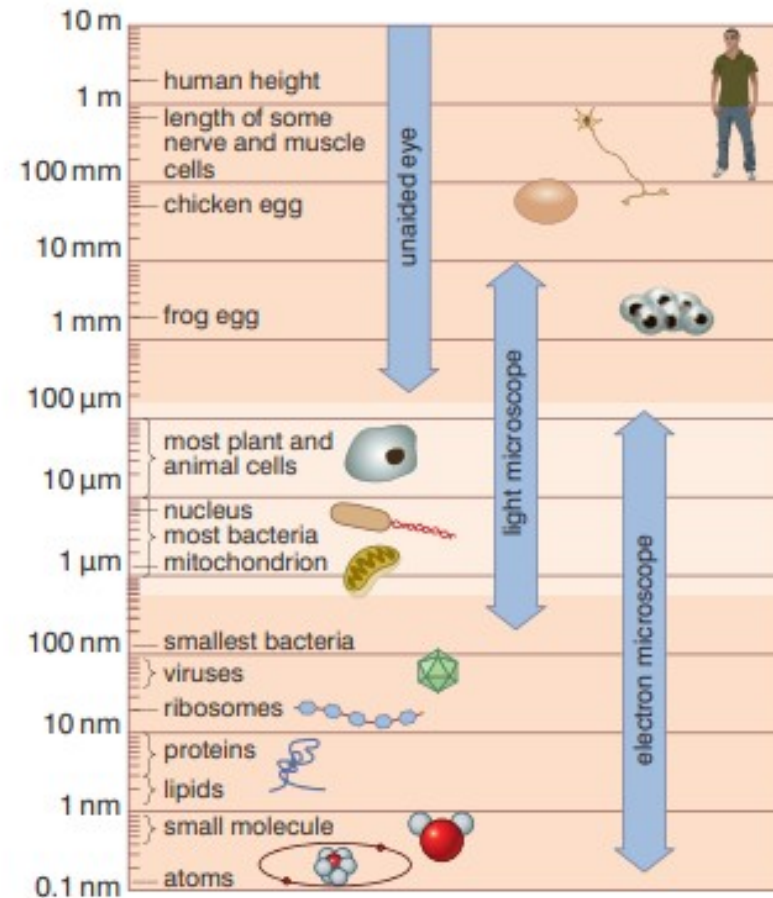


Figure 4.9 Size and scale in living things

3.2. Types of Cells

By the end of this section you should be able to:

- Appreciate that there are just two basic types of cells: **prokaryotic** and **eukaryotic** cells.
- Give examples and describe the basic structure of each type.
- Explain the difference between prokaryotic and eukaryotic cells.

Prokaryotic cells

- a type of cell that **does not have a nucleus**. The word prokaryotic is derived from Greek **pro** (**before**) and **karyos** (**nuclear**).
- 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 specialized regions for certain functions.

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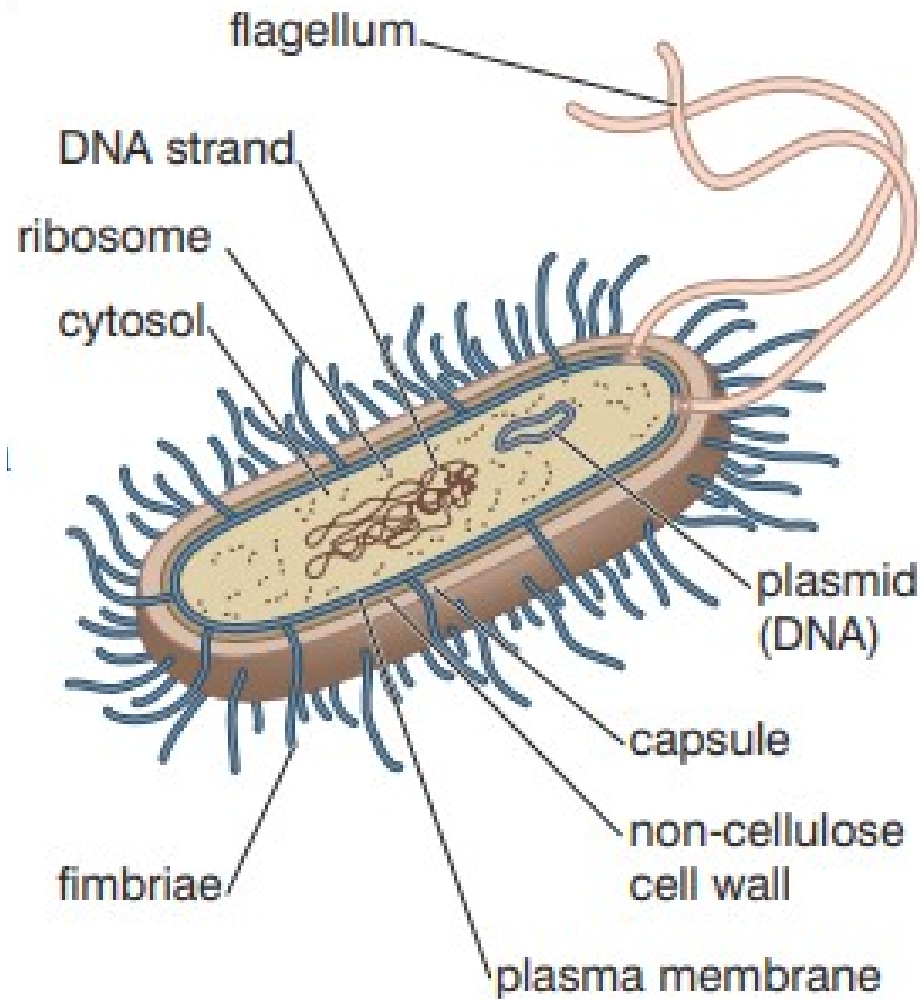
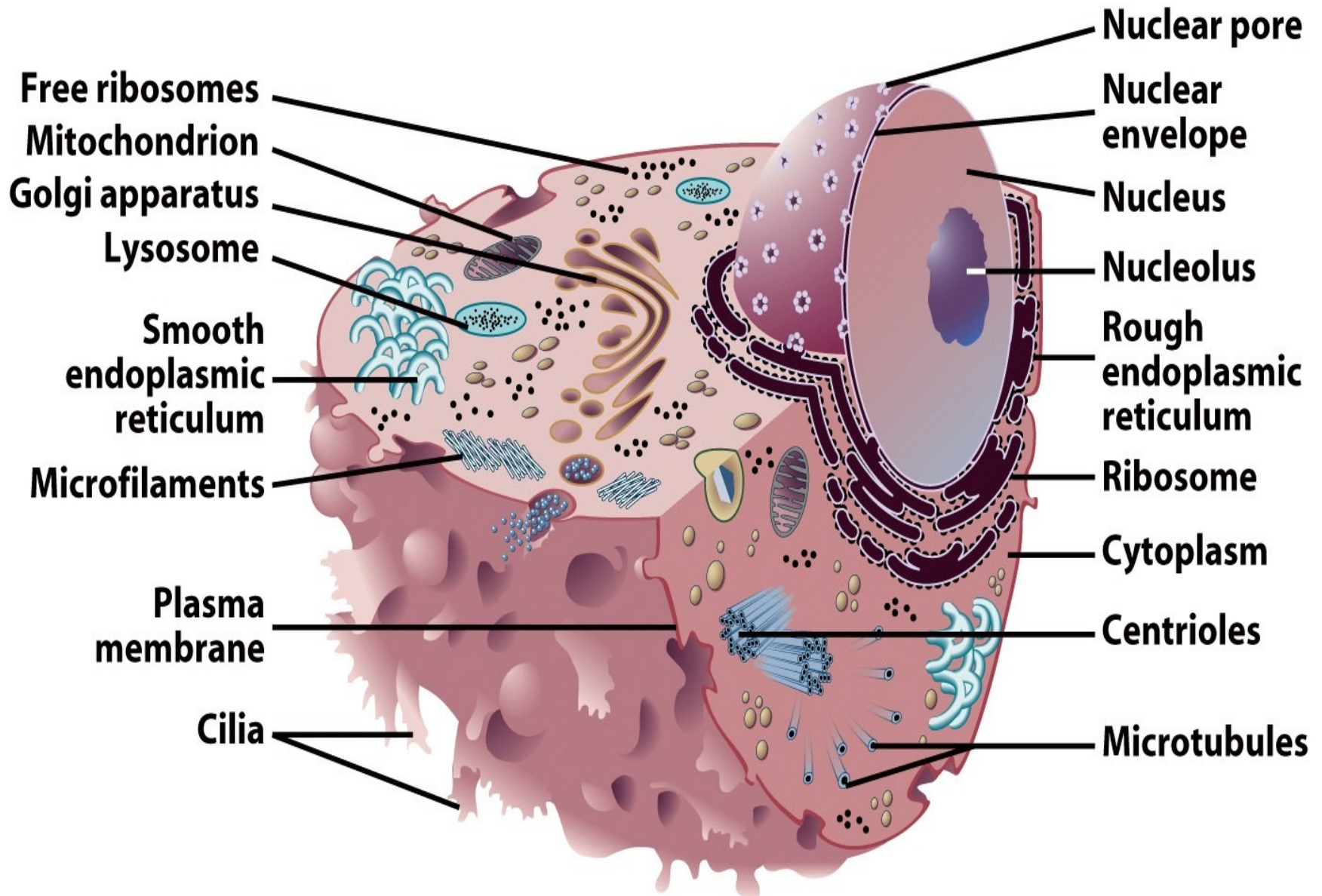


Figure 4.14 *A generalised prokaryotic cell*

Representative- Animal Cell



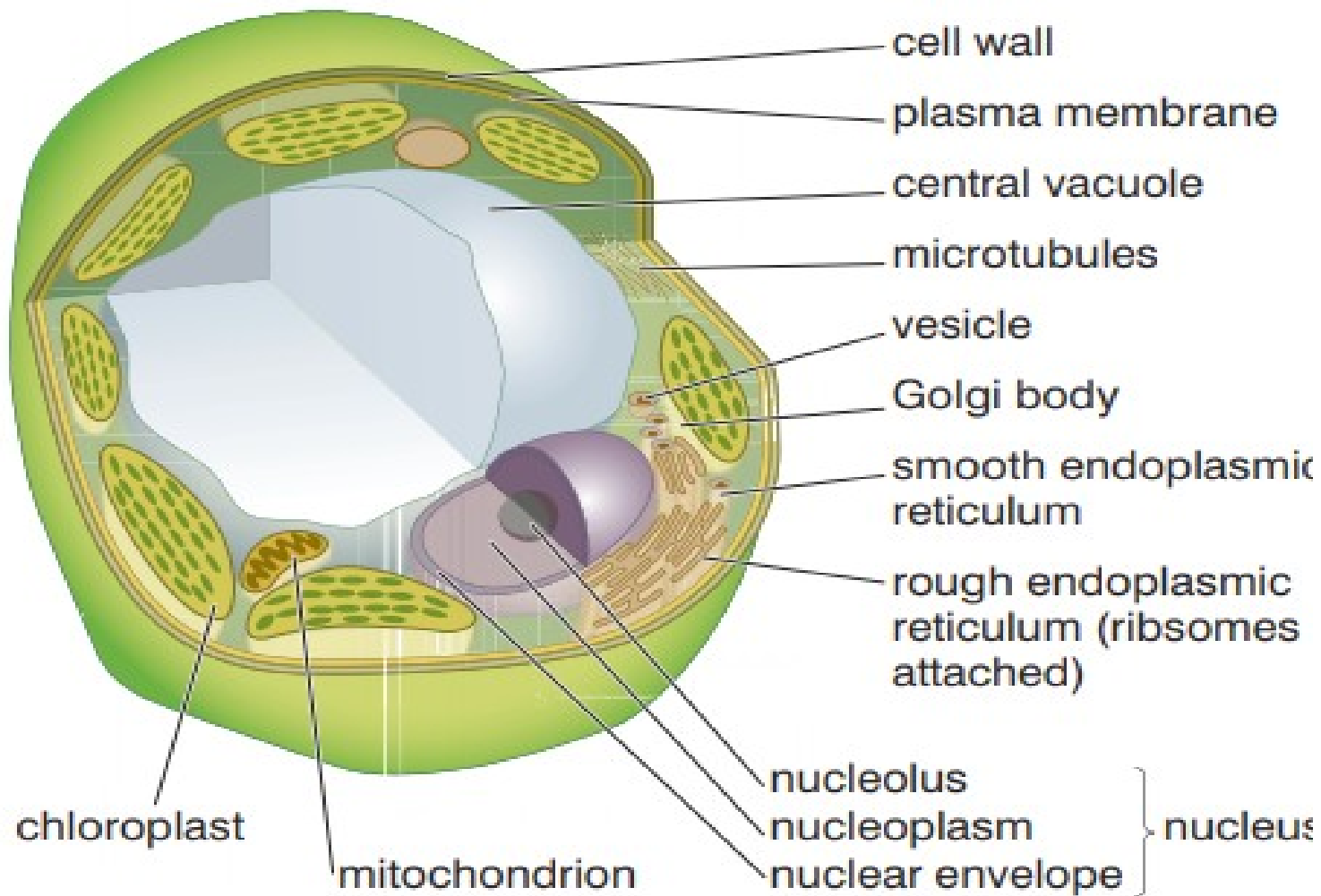


Figure 4.16 A generalised plant cell

prokaryotic cell *a type of cell that does not have a nucleus. The word prokaryotic is derived from Greek pro (before) and karyos (nuclear)*

eukaryotic cell *a type of cell that has a nucleus. The word eukaryotic is derived from Greek eu (true) and karyos (nuclear)*

organelles *individual structures in a cell with a specific function*

endoplasmic reticulum *the network of membranes in a cell*

membrane-bound organelles *organelles surrounded by membranes*

These are clearly much more complex cells than the prokaryotic cell. What is really different about them is that 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 (if present)
- lysosomes
- Golgi apparatus

These are called **membrane-bound organelles**.

These membranes make the cell able to function more efficiently. Because each mitochondrion is enclosed by a membrane (actually by two membranes!), the reactions that take place here are not affected by other cellular reactions. The same applies to the other membrane-bound organelles. Also, membranes of the endoplasmic reticulum separate areas of the cytoplasm and allow them to function independently.

How did eukaryotic cells originate?

‘modern’ eukaryotic cell was formed when several of the more primitive prokaryotic cells ‘got together’.

The plasma membrane around the cell became more and more ‘infolded’ until there was an extensive membrane system in the cell.

- ✓ This would eventually evolve into the endoplasmic reticulum (EPR) of eukaryotic cells.

The next stage in the theory suggests that this membranous cell engulfed other smaller cells that were better at respiring organic molecules to release energy.

Cont...

- These 'engulfed' prokaryotes would evolve into the mitochondria of eukaryotic cells.
- The cells that contained them were **heterotrophic** and the forerunners of animal, fungal and protoctistan cells.
- One further stage suggests that some of these cells with their 'primitive mitochondria' also engulfed other, smaller, prokaryotic cells.
 - These were prokaryotic cells that could photosynthesise and would, in time, evolve into chloroplasts.
 - The cells that contained these would be **autotrophic** and the forerunners of plant cells.
 - This theory of the origin of eukaryotic cells is called the **endosymbiont theory** and was first proposed by the biologist **Lynn Margulis**.

Table 4.2 *A summary of the main 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 • Not associated with protein to form chromosomes	• Linear DNA • 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 • Not made from cellulose (often made from peptidoglycan)	• Present in plant cells, algal cells and fungal cells • Cellulose in plant cells, various materials in other cells

3.3 Parts of the cell and their functions

By the end of this section you should be able to:

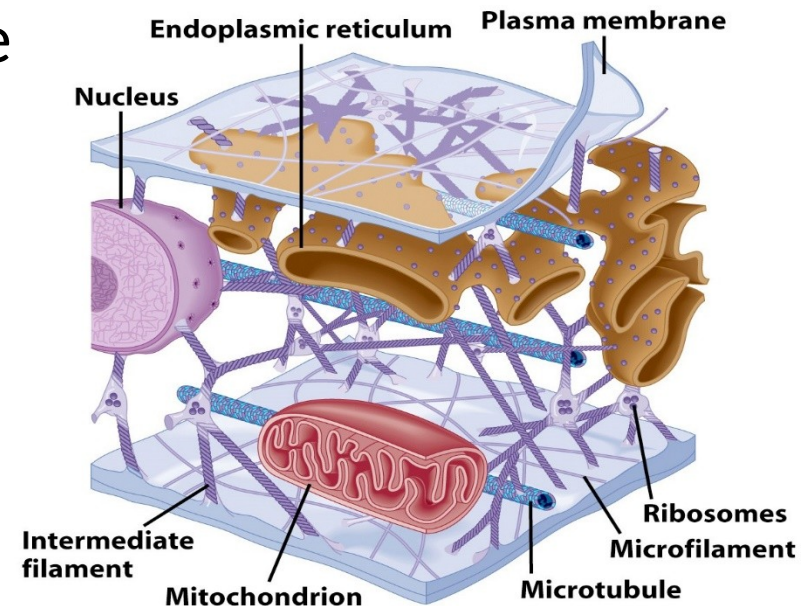
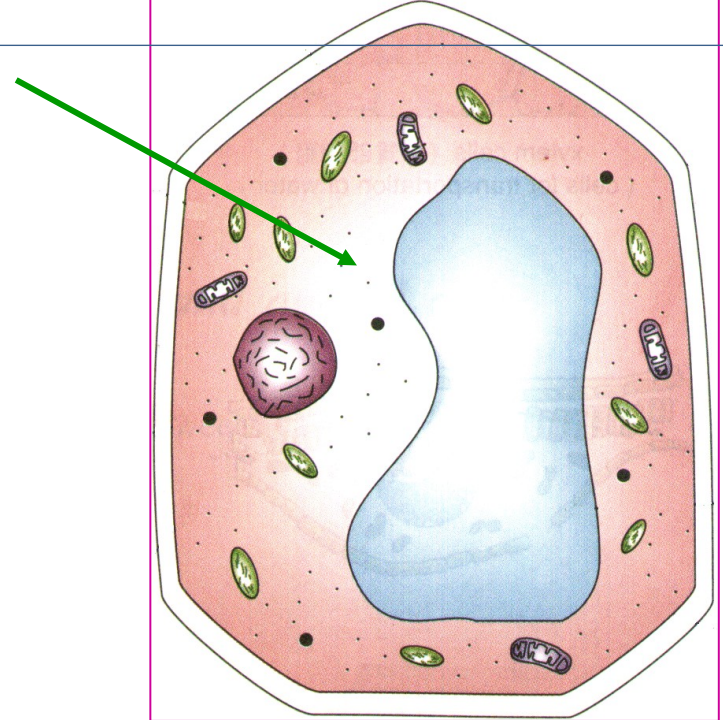
- Discuss the importance of a cell membrane.
- Describe the composition and arrangement of lipids and proteins in the membrane.
- Compare the Davson–Danielli and fluid mosaic models.
- Construct and show the arrangement of the phospholipids and proteins in the fluid mosaic model.
- Explain the role of glycoprotein and other components in the cell membrane.
- Name the different parts of the cell and explain their functions.
- State and explain the mechanisms of substance transport across a cell membrane.

Cytoplasm

- The **cytosol** is the material of cell interior not occupied by the nucleus,
 - ✓ containing a number of distinct, highly organized membrane-enclosed structures
- Organelles are dispersed within a complex **jelly-like substance enclosed by cell membrane** called the cytosol.
- All cells contain six main types of organelles such as endoplasmic reticulum, Golgi complex, lysosomes, peroxisomes, mitochondria, and vacuoles.
- They are similar in all cells, but with some variations depending on the cell specialization.

Cytoplasm cont'd

- Provides a medium for **chemical reactions** to take place
- Contains **organelles** to carry out specific functions
- Found in **all** cells
- Viscous fluid containing organelle
- components of cytoplasm
 - Interconnected filaments & fibers
 - Fluid = cytosol
 - Organelles
 - storage substances



Cell organelles

- ❖ An organelle is a **specialized subunit within a cell** that has a specific function.
- ❖ In eukaryotes an organelle is a membrane bound structure found within a cell.
- ❖ **Prokaryotes** are cells that **don't have membrane bound organelles**.
- ❖ **These organelles are found in the cytoplasm**, a viscous liquid found within the cell membrane.
- ❖ May or may not be **membrane-bound and microscopic**

Cont'd

❑ **Based on membrane covering, there are two kinds of cell organelles**

- 1. Membranous organelles** eg. Endoplasmic reticulum (Rough and Smooth), Golgi bodies, mitochondria, chloroplasts, nucleus, lysosomes, peroxisomes and vacuoles are membranous.
- 2. Non-membranous organelles** e.g. ribosomes, centrosomes, cilia and flagella, microtubules, basal bodies and microfilaments.

Structure and function of organelles

A. Nucleus: is distinctly **oval or spherically shaped** largest central structure **surrounded by a double-layered membrane.**

- In the nucleus, **DNA directs protein synthesis** and serves as a genetic blueprint during cell replication.
- Controls normal activities of the cell
- **Bounded by nuclear envelop** (membrane with pore)
- Three types of RNA are involved in protein synthesis.
 - ✓ **mRNA, tRNA and rRNA**

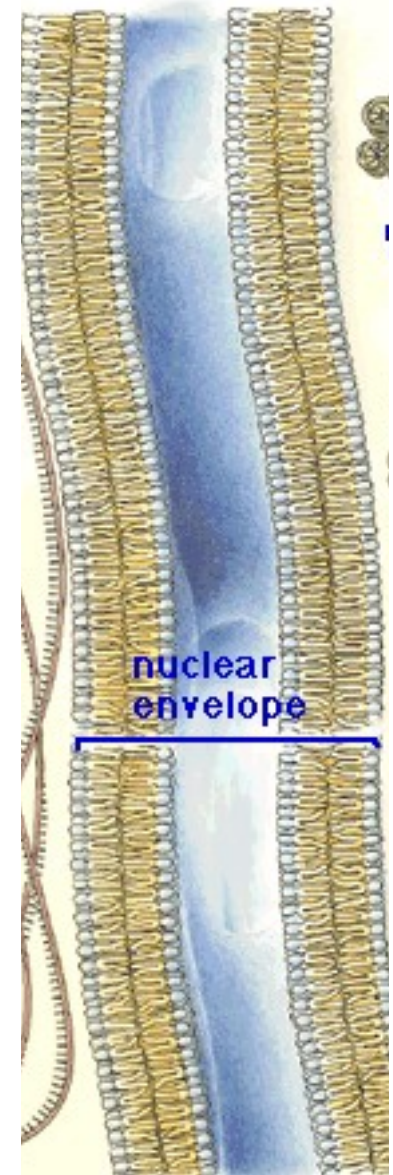
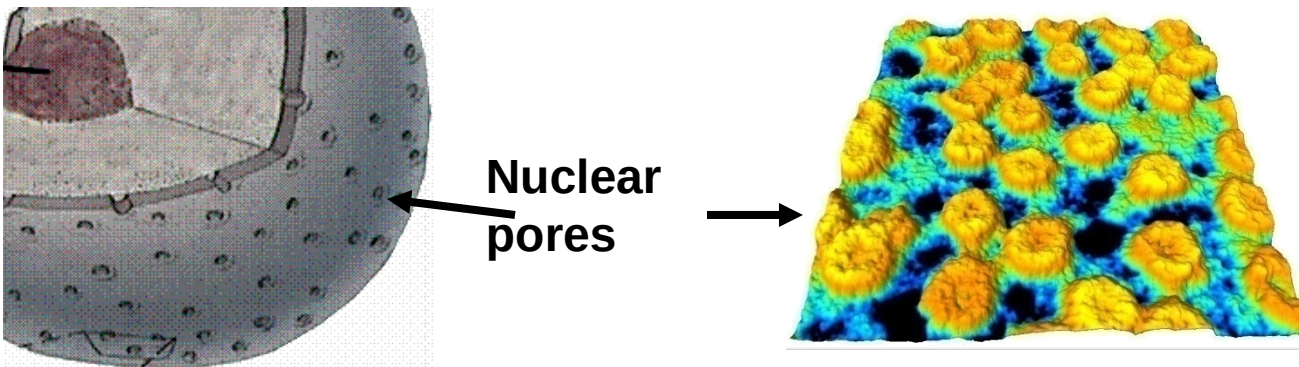
Cont'd

Generally, the nucleus may be:

- **Rounded** e.g. in hepatocytes.
 - **Indented** (segmented) e.g. in neutrophils.
 - **binucleated** e.g. in parietal cells (epithelial cell in stomach), cardiac muscle cells.
 - **multinucleated** e.g. in osteoclasts, skeletal muscle cells.
 - **very large** (many DNA) e.g. in megakaryocytes
 - **absent** e.g. in mature erythrocytes, blood platelets.
- ❖ The nucleus is surrounded by a **nuclear envelope** and contains **chromatin** and one or more **nucleoli**.

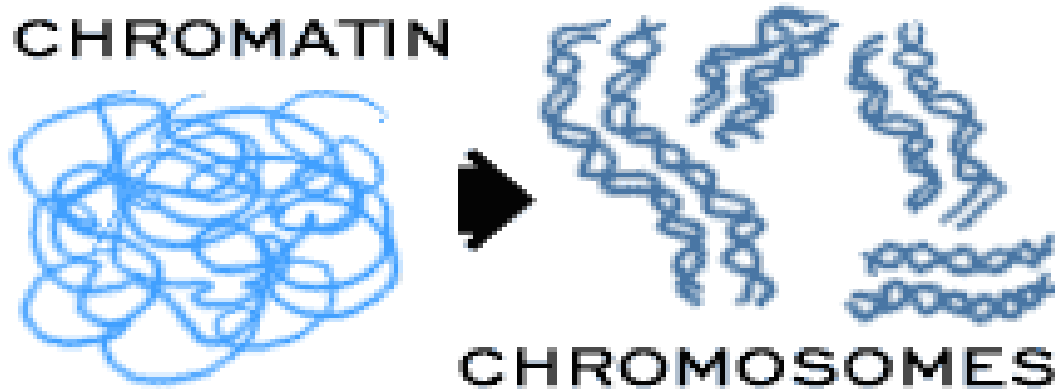
Nuclear Envelope

- **Double membrane** surrounding nucleus
- Consists of outer and inner membrane
- Also called **nuclear membrane**
- Contains **nuclear pores** for materials to enter & leave nucleus
- Through this pores most **ions** and **water soluble molecules** to transfer b/n nucleus and cytoplasm.
- **Connected to the rough ER**



Inside the Nucleus

The genetic material (DNA) is found in nucleus



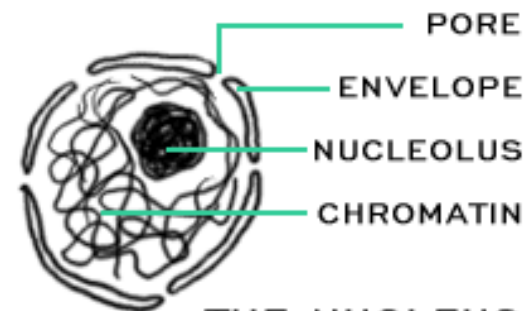
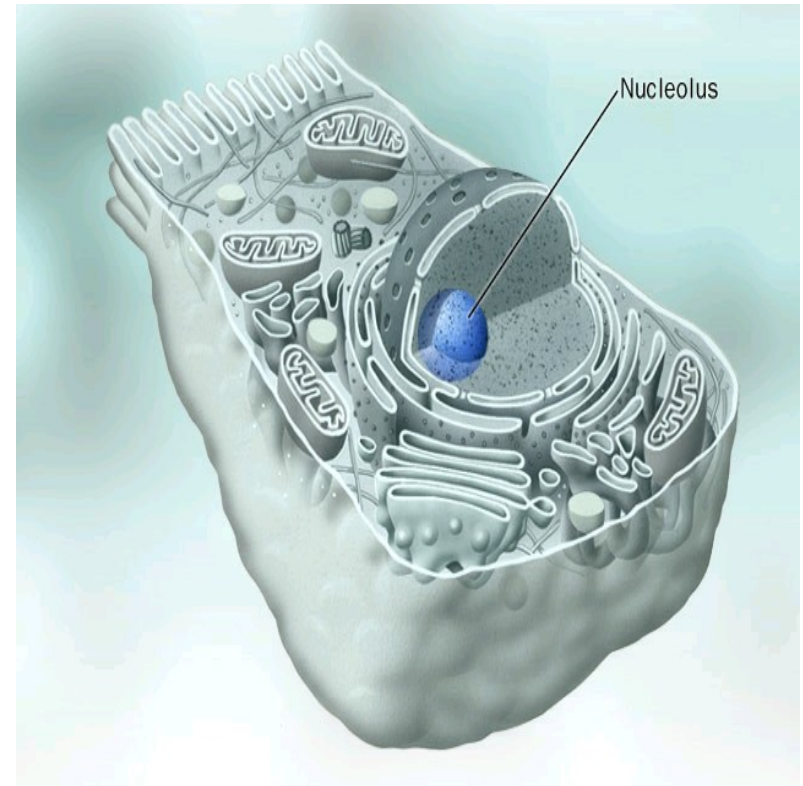
DNA is spread out
and appears as
CHROMATIN
in non-dividing cells

DNA is condensed &
wrapped around proteins
forming
as **CHROMOSOMES**
in dividing cells

- **Chromatin:** is a **colored material** and easily stained for viewing with microscope
 - ✓ It is composed mainly of coils DNA bound to basic protein called histones.
 - ✓ It is composed of DNA and proteins that condense to form chromosomes. The histone proteins organize the DNA into special structures called nucleosomes. The nucleosome further folds to form a chromatin fibre.
- **Nucleoli:** is nuclei of most cells contain one or more lightly stained structures called nucleoli that actively **engage in synthesizing of ribosomes.**

Nucleolus

- Inside nucleus
- Cell may have 1 to 3 nucleoli
- Disappears when cell divides
- Makes ribosomes that make proteins



THE NUCLEUS

Nucleus

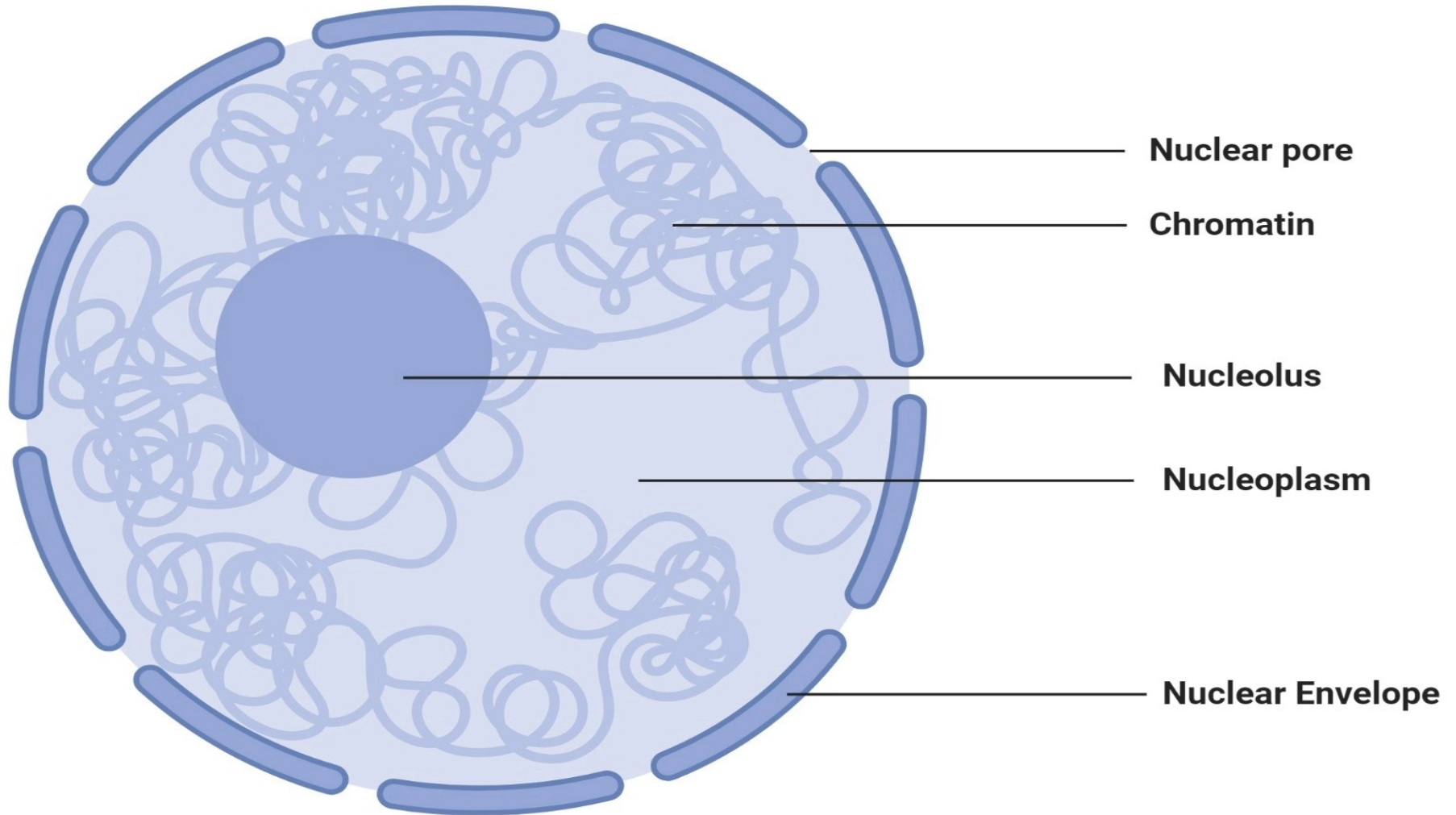


Figure: Nucleus, Image Copyright © Sagar Aryal, www.microbenotes.com

B. Endoplasmic Reticulum - ER

- **Fluid-filled membrane system** extensively present throughout the cytosol
- Network of hollow membrane tubules
- Connects to nuclear envelope & cell membrane
- Functions in Synthesis of cell products & Transport
- **ER membrane contains enzymes** required for the synthesis of almost all the lipids needed for the production of new membranes
- **Two types: Rough ER and Smooth ER**

Rough Endoplasmic Reticulum (Rough ER)

- **Rough ER** projects outwards from the reticulum as stacks of flattened sacs.
- Has **ribosomes** on its surface
- Associated with ribosomes to produce and releases variety of proteins
- Makes membrane proteins and **proteins for export out of cell**
- Proteins are made by **ribosomes on ER surface**
- They are then **threaded into the interior of the Rough ER** to be modified and transported

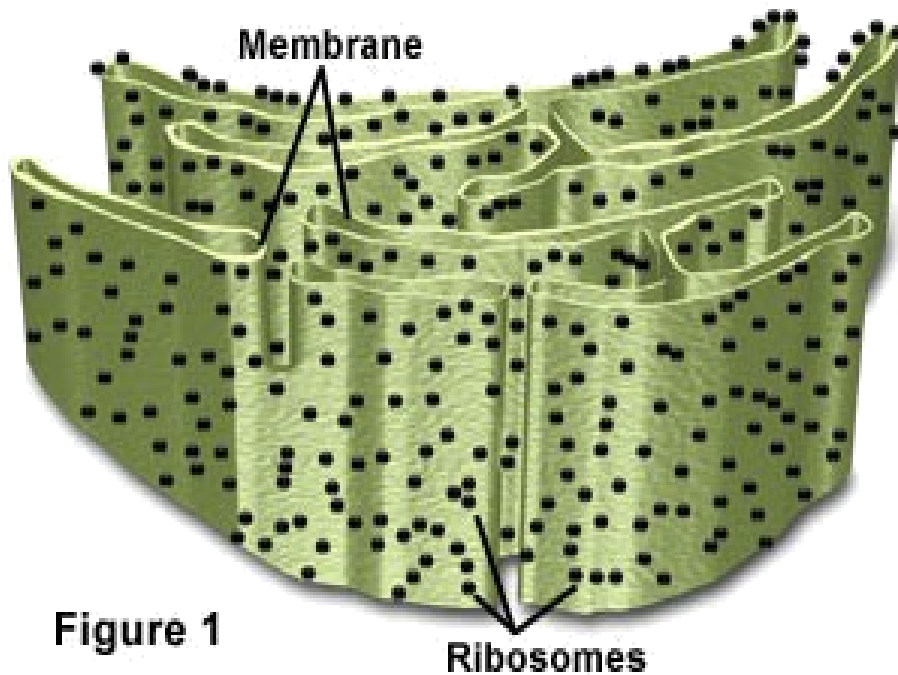
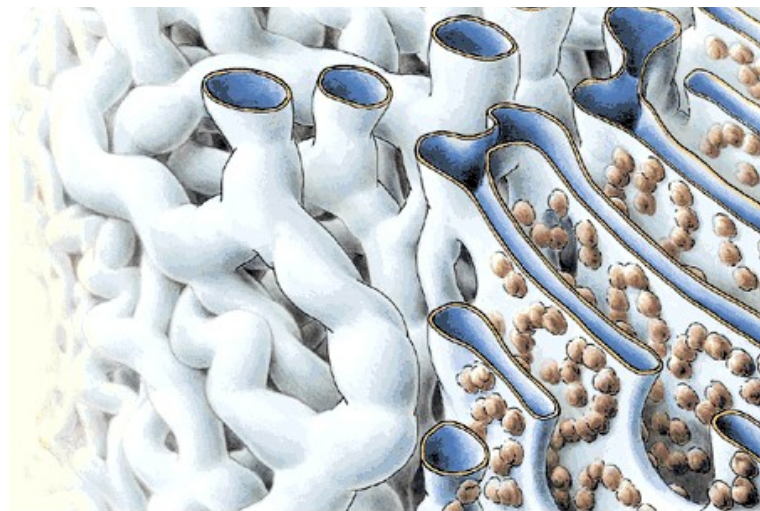


Figure 1

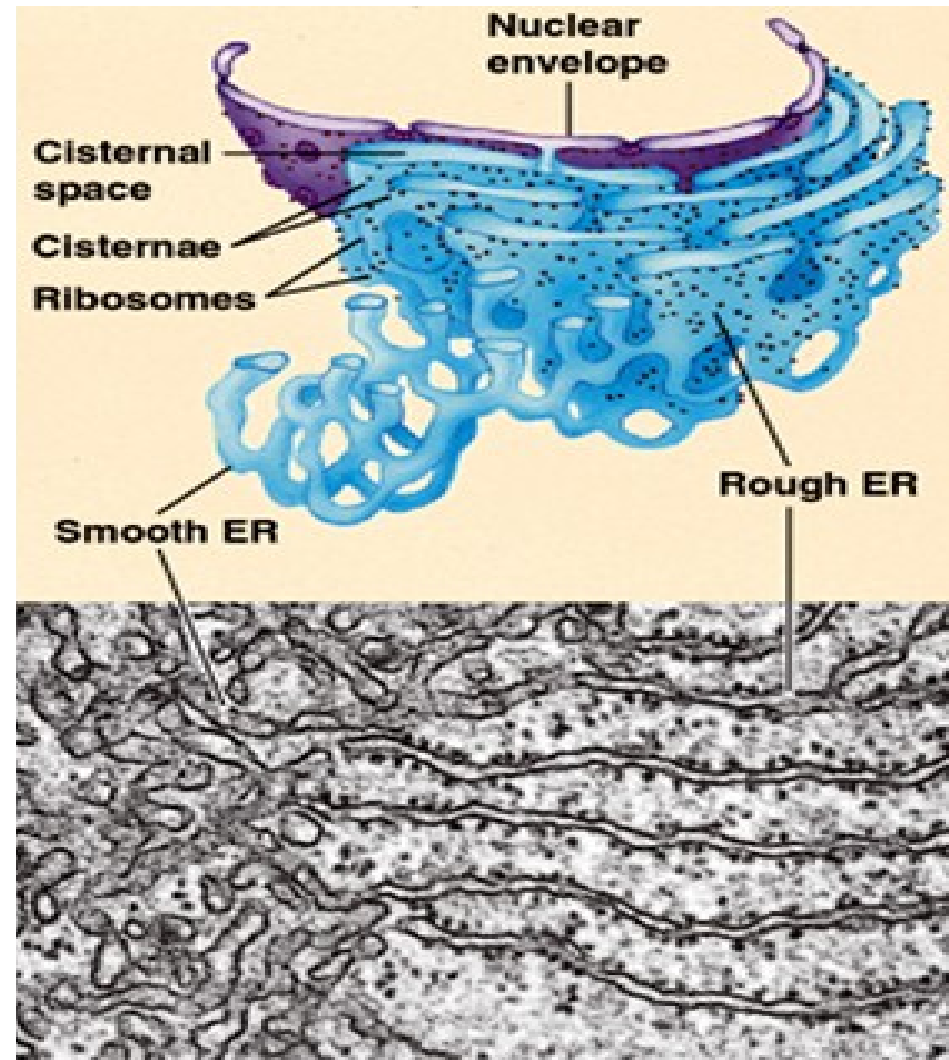


Fig. Rough and Smooth ER

Smooth Endoplasmic Reticulum (Smooth ER)

- **Smooth ER** is a meshwork of interconnected tubules
- **Does not have ribosomes**, thus does not produce proteins.
- **Is attached to the ends of rough ER**
- It serves a variety of other functions that differ in cell types.
 - Serves in **packaging** and **discharging** site for protein molecules that are to be transported from the ER
- Portions of the smooth ER then **giving rise to transport vesicles**

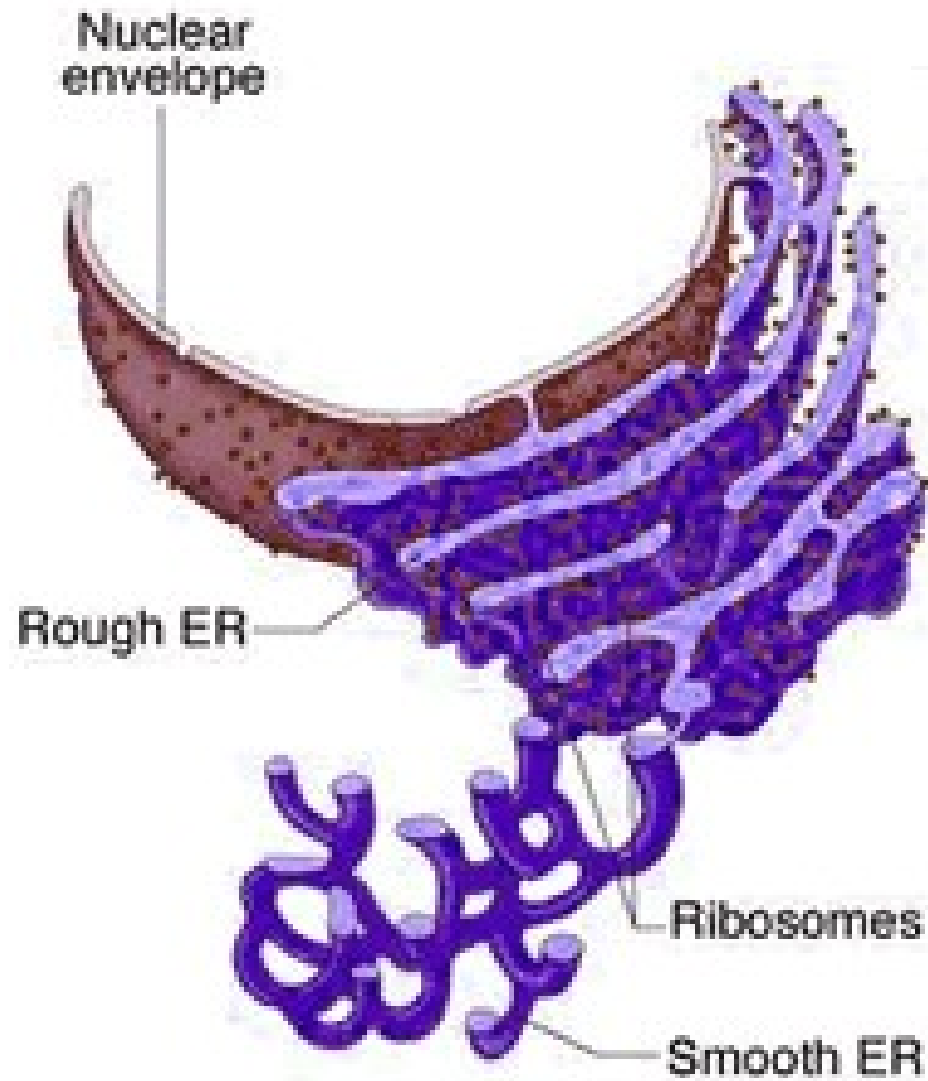


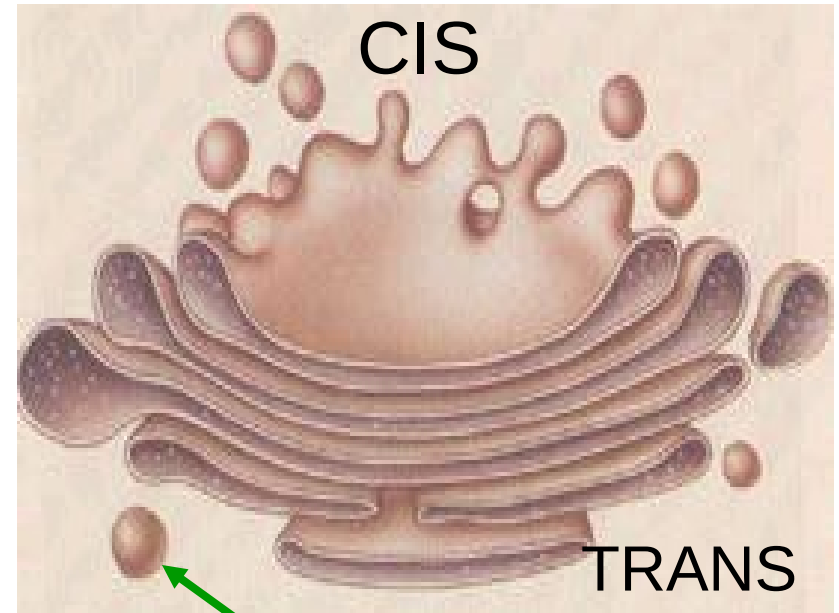
Fig. Rough and Smooth ER

Functions of the Smooth ER

- **Smooth ER makes membrane lipids (steroids) contains** enzymes for the synthesis of lipids
- In the **liver** and **kidney cells**, it is responsible for the detoxification and inactivation of drugs. E.g. alcohol, pesticides, and carcinogens.
- In **skeletal muscle cells**, a modified form of smooth ER stores Ca^{2+} to be released for muscle contraction.

C. Golgi Bodies

- Elaborately associated with the ER and contains sets of flattened, curved, membrane-enclosed sacs
- Have a shipping side (trans face) and receiving side (cis face)
- Receive proteins made by ER
- Transport vesicles with modified proteins pinch off the ends

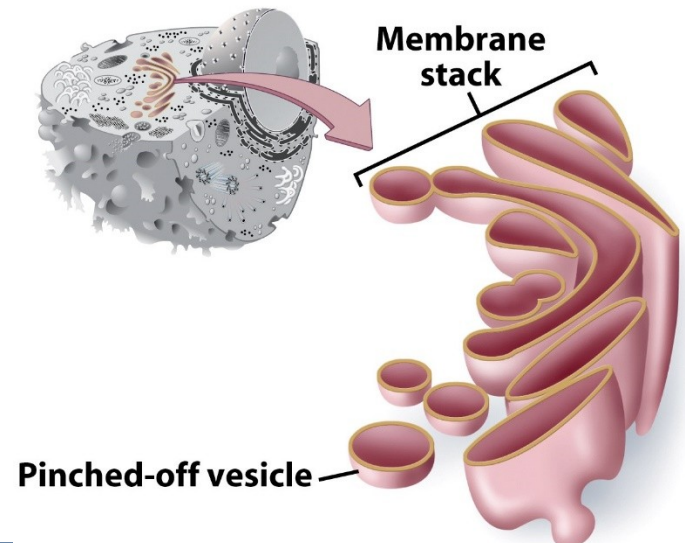


Transport
vesicle

Golgi-complex cont'd

It performs the following important functions

1. Processing the raw material into finished products
 2. **Modify, sort and package** molecules from ER for **storage** or **transport** out of cell
- Materials are transported from Rough ER to Golgi to the cell membrane by **vesicles**



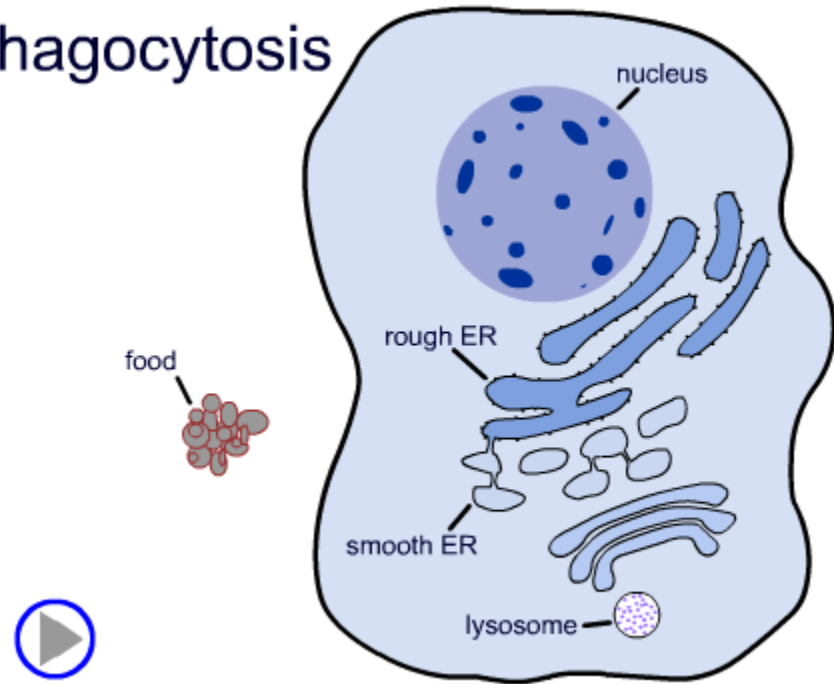
D. Lysosomes

- Lysosomes are **membrane-enclosed sacs** containing powerful **hydrolytic enzymes capable of digesting** and **removing unwanted** cellular debris and foreign materials such as bacteria that have been internalized within the cell.
- It serve as the intracellular-digestive system.
- Are vary in size and shape, and about 300μm in a cell.

Lysosome Digestion

- Cells take in food by **phagocytosis**
- Lysosomes **digest** the food & get **rid of wastes**

Phagocytosis



E. Peroxisome

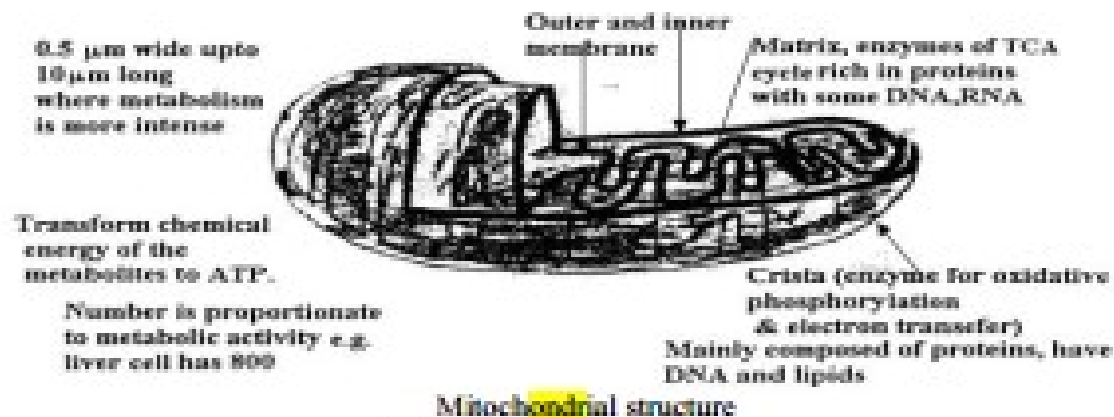
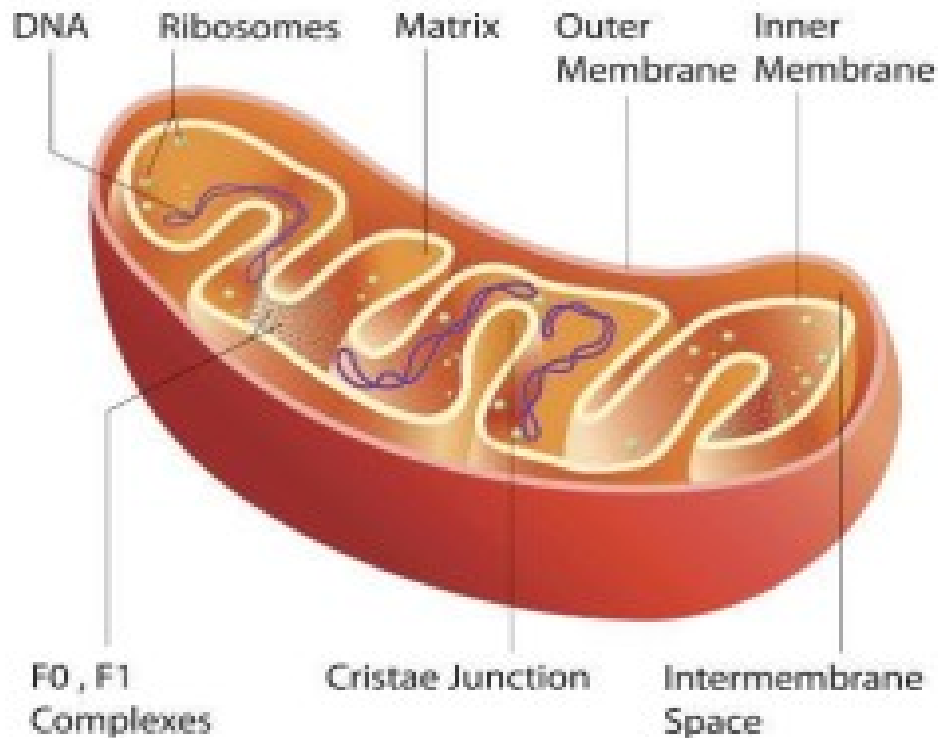
- ❖ **Peroxisome** is membrane-enclosed sacs containing **oxidative enzymes** and **catalase** that detoxify various wastes.
- ❖ **Peroxisomal disorders** disrupt the normal processing of lipids and can severely disrupt the normal function of the nervous system by altering the structure of the nerve cell membrane

F. Mitochondria

- **Mitochondria** are the '**power houses**' of a cells
 - ✓ They extract energy from nutrients in food and
 - ✓ Transform it into usable form to energize cell activity.
 - ✓ Their number varies depending on the energy needs of each particular cell types.
 - ✓ A single cell may have few hundreds or thousands.
 - ✓ Are rod or oval shaped about the size of a bacterium.

Mitochondria are unusual organelles in two ways

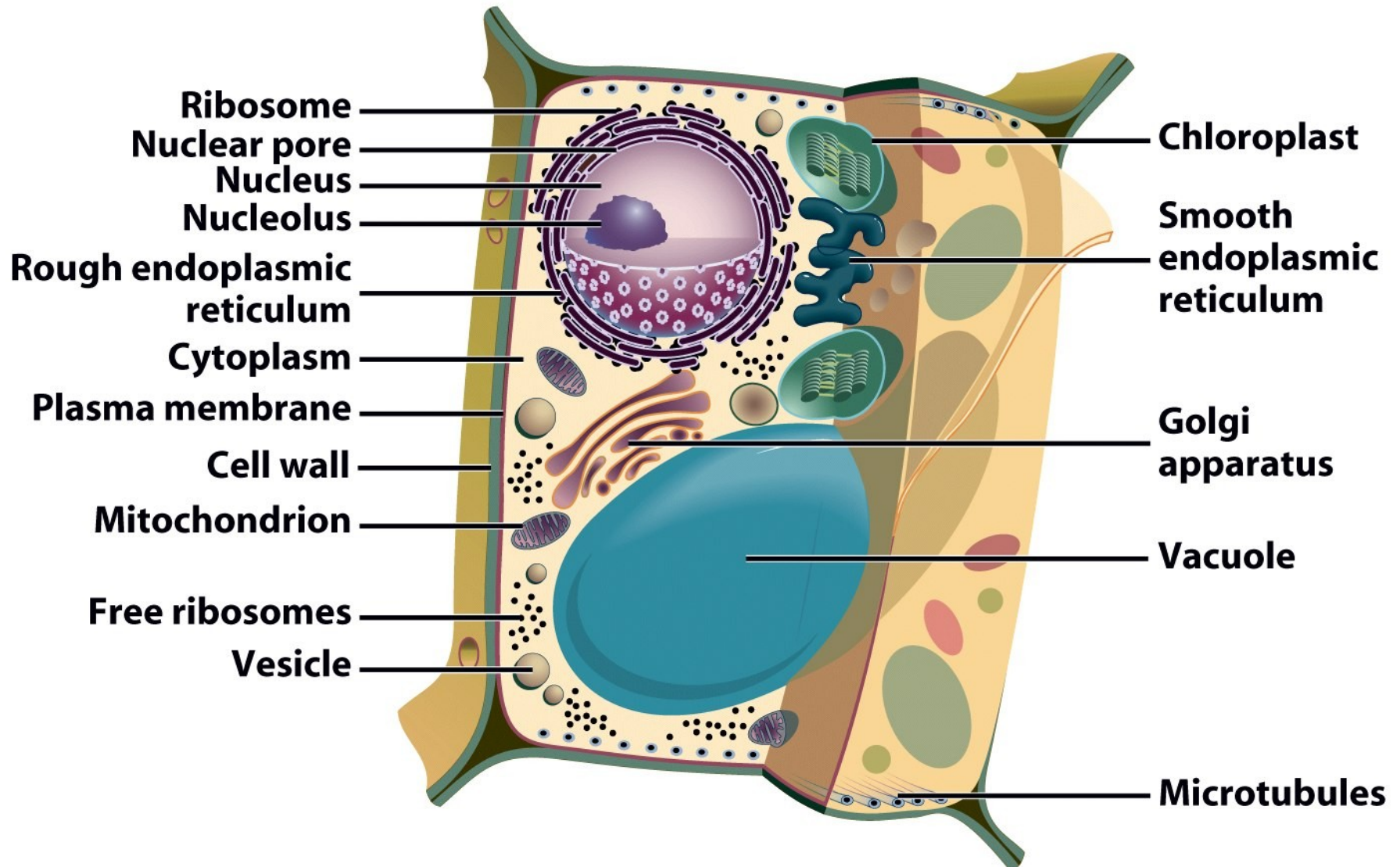
1. In the matrix they have their own unique DNA called **mitochondrial DNA**.
2. Mitochondria **have the ability to replicate themselves** even when the cell to which they belong is not undergoing cell division.



G. Chloroplasts

- Are the photosynthetic organelles of plants and algae
- They are located in outer surface of the cell to receive enough light.
- Are **green colored** due to the chlorophyll pigments found in its internal parts.

Representative-Plant Cell



H. Vesicles

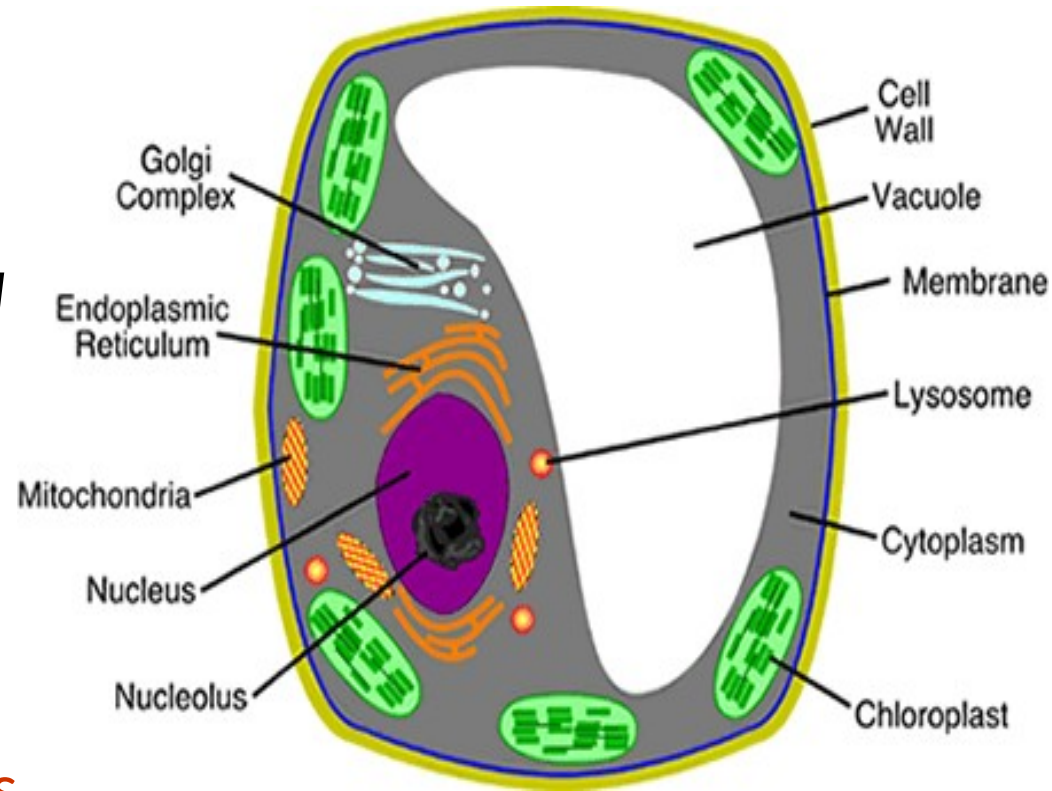
- ✓ are membrane bound sacs that are used to store or transport substances around the cell.

I. Vacuoles

- ✓ Are essentially larger Vesicles, and are formed by joining many Vesicles.
- ✓ Are membrane bound organelles that have no specific shape
- ✓ Their function varies greatly depending on the type of cell
- ✓ In plant cells they are important in maintaining Turgor Pressure.

Vacuoles cont'd

- Fluid filled sacks for storage
- **Small or absent** in *animal* cells
- *Plant* cells have a **large Central Vacuole**
- In plants, they store **Cell Sap**
- Includes storage of **sugars, proteins, minerals, lipids, wastes, salts, water, and enzymes**

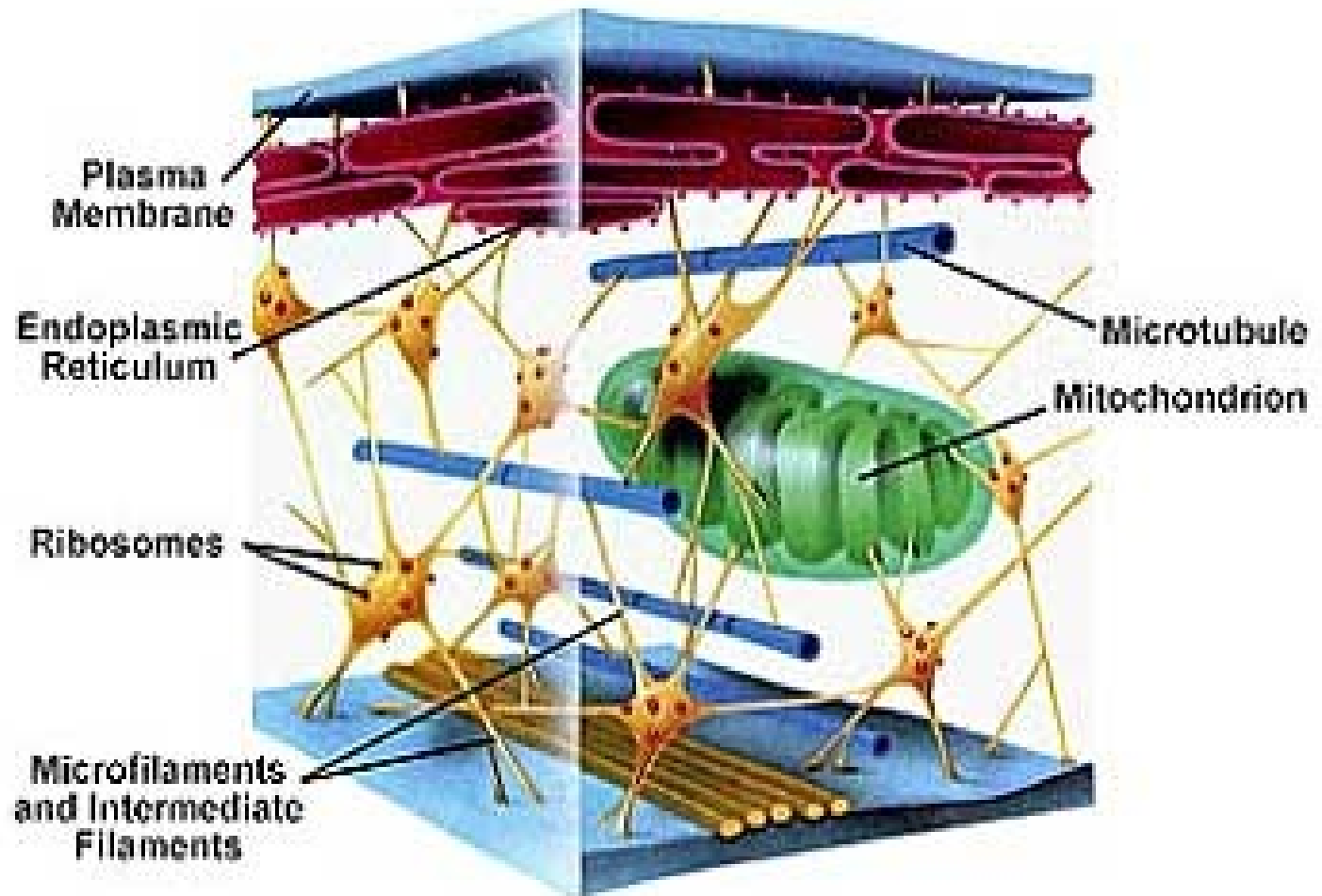


K. Cytoskeleton

- ❖ It is a complex protein network that act as the bone and muscle of the cell.
 - Provides/determine/maintain cell shape
 - Provides structural support of cell
 - Also help **move organelles** around (cilia, flagella, intra-cytoplasmic vesicles)
 - Contribute to movement of a cell as a whole
- ❖ This network has at least four distinct elements: **Microtubules**, **Microfilaments**, **Intermediate filaments** and **Microtubular lattice**

Cytoskeleton cont'd

- **Microfilaments** are threadlike and made of **actin**
- **Microtubules** are tubelike & made of **tubulin**

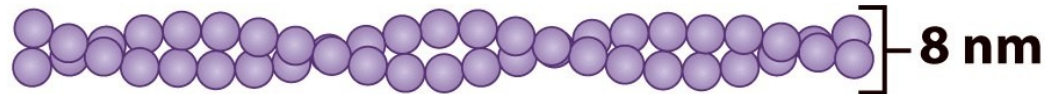


Cytoskeleton cont'd

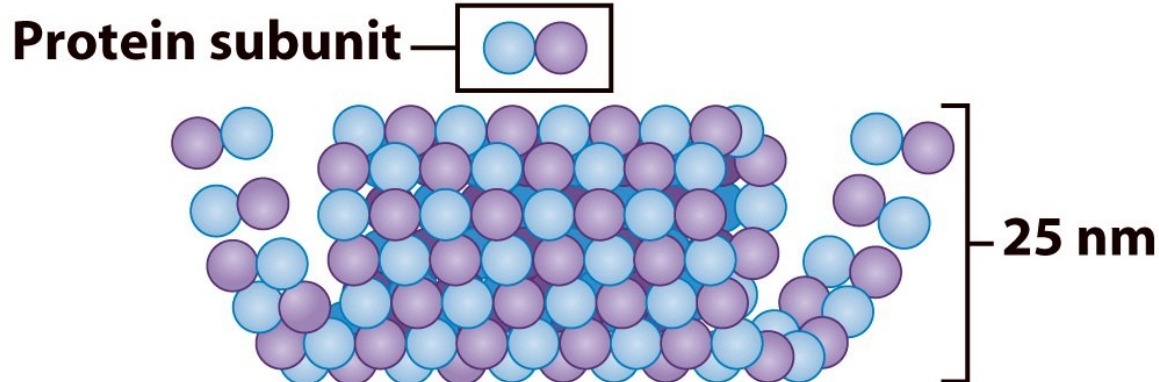
- **Microfilaments** are important to cellular contractile system and as mechanical stiffeners (rigidity).
- **Microtubule** is the largest of the group; slender, long, hollow tubes composed of a globular protein molecule. They provide asymmetrical shape to the cell, such as a neuron with cell body and long axon
- **Intermediate filaments**- extending from a ring surrounding the nucleus to the plasma membrane
 - ✓ provide a scaffold that integrates the components of the cytoskeleton and organizes the internal structure of the cell.

Cytoskeleton cont'd

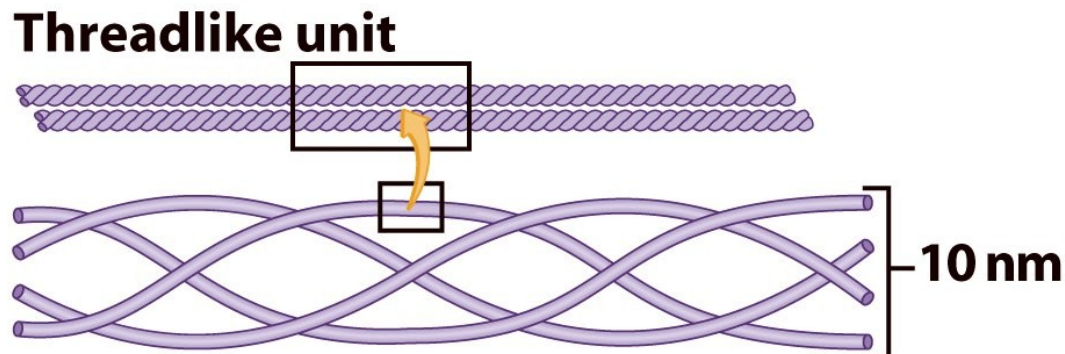
(a) Microfilament



(b) Microtubule



(c) Intermediate filament

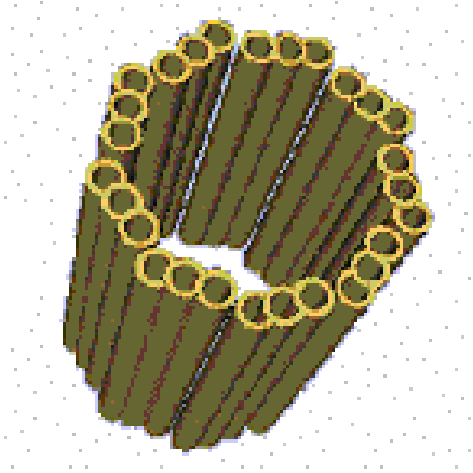


Cilia and Flagella

- Bundle of microtubules
- Provide motility
- Cilia
 - Short
 - Used to move substances outside human cells
- Flagella
 - Whip-like extensions
 - Found on sperm cells



Centrioles

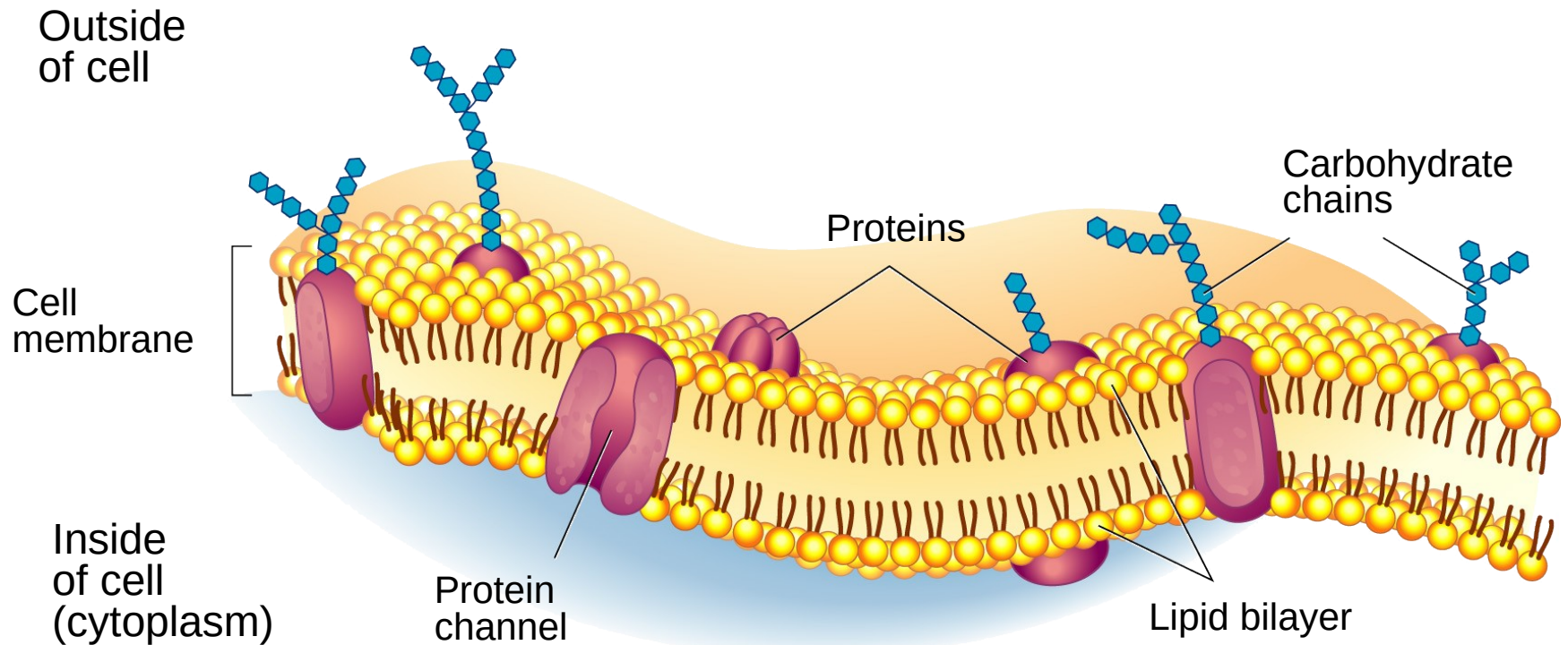


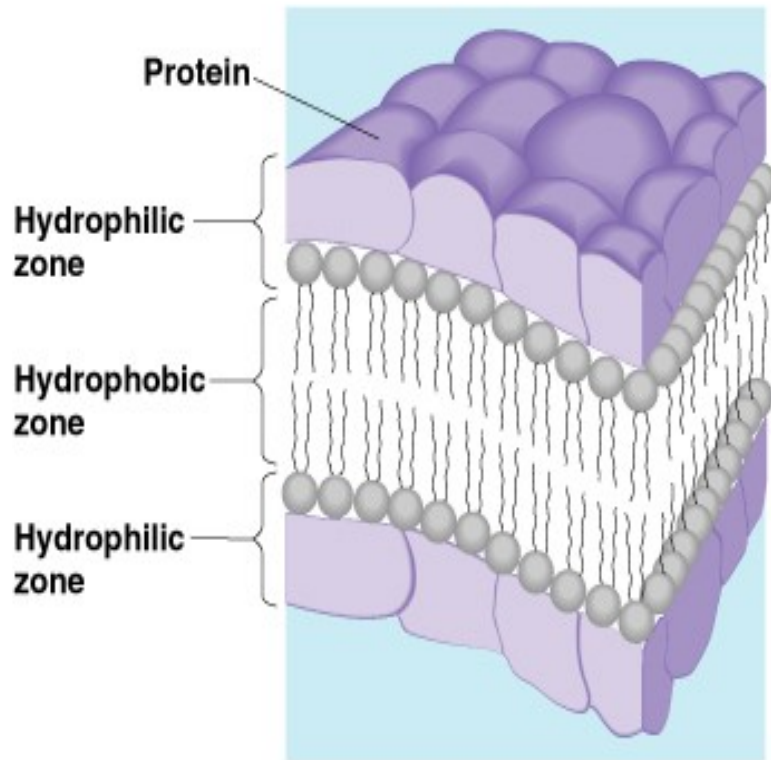
- Found only in **animal** cells
- **Paired** structures near nucleus
- Made of bundle of **microtubules** (**tubulin**)
- Appear during **cell division** forming **mitotic spindle**
- Help to **pull chromosome pairs apart** to opposite ends of the cell

Plasma/cell membrane

- It is thin layer of **lipids** and **proteins** forming outermost boundary of living cell
- Enclosing the intracellular fluid (ICF).
- It serves as a **mechanical barrier** that traps needed molecules within the cell.
- Play a **role in determining the composition of cell** by selective permeability of substances to pass between the cell and its ECF environment.

- Composed of **double layer of phospholipids** and **proteins**
- **Surrounds** outside of all cells

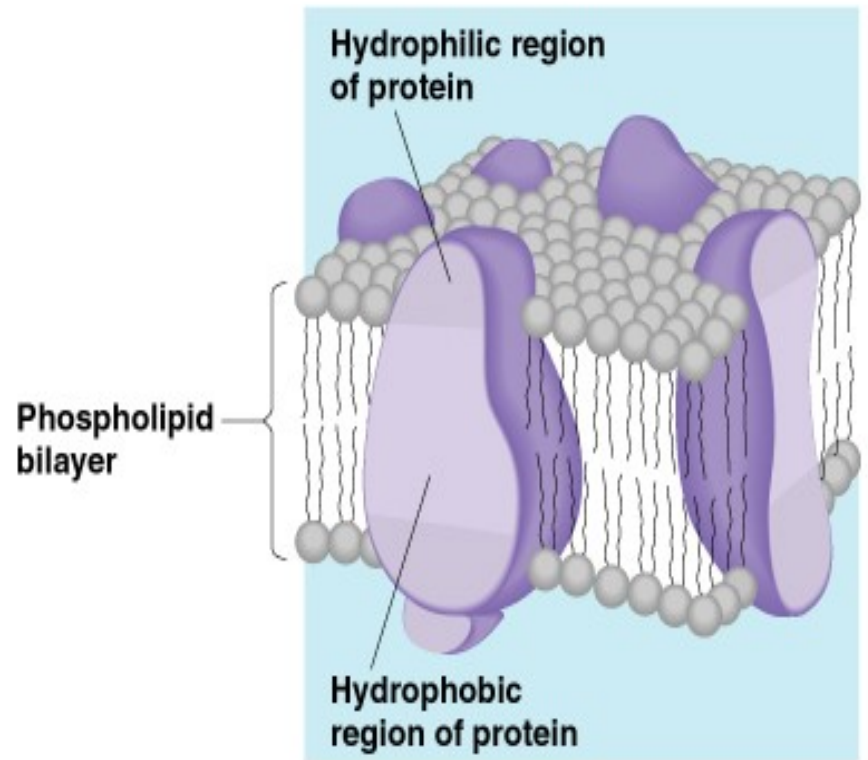




(a) Original Davson-Danielli model

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lipo-protein sandwich

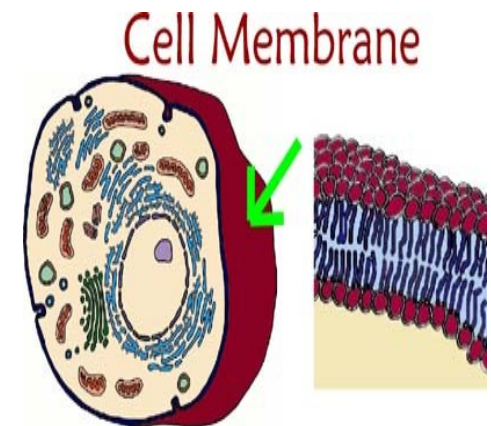
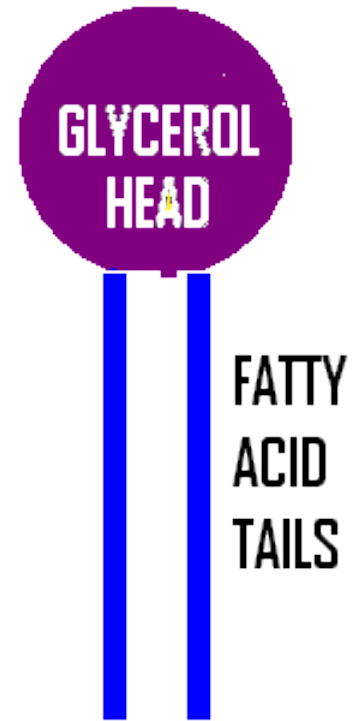


(b) Current fluid mosaic model

a membrane is a collage of different proteins, often clustered together in groups, embedded in the fluid matrix of the lipid bilayer

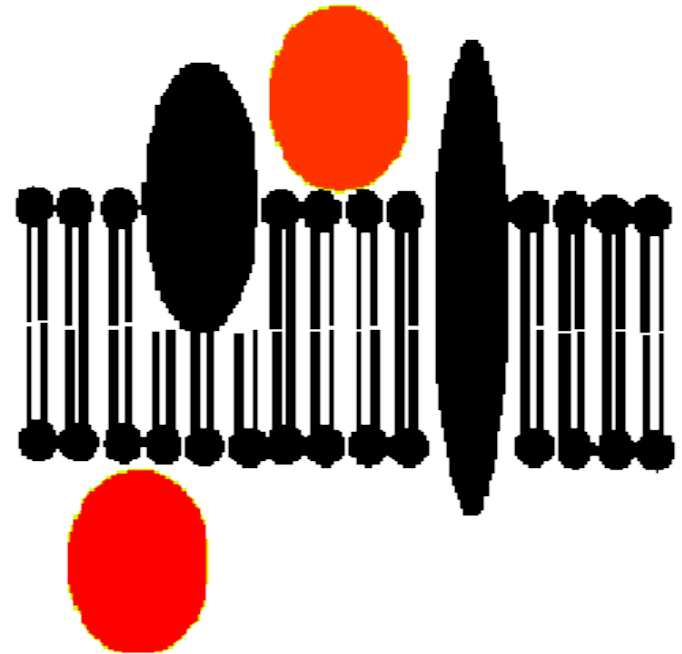
Phospholipids

- Heads contain **glycerol & phosphate** and are **hydrophilic** (attract water)
- Tails are made of **fatty acids** and are **hydrophobic** (repel water)
- Make up a **bilayer** where **tails** point **inward** toward each other
- Can **move laterally** to **allow small molecules** (O_2 , CO_2 , & H_2O to enter)

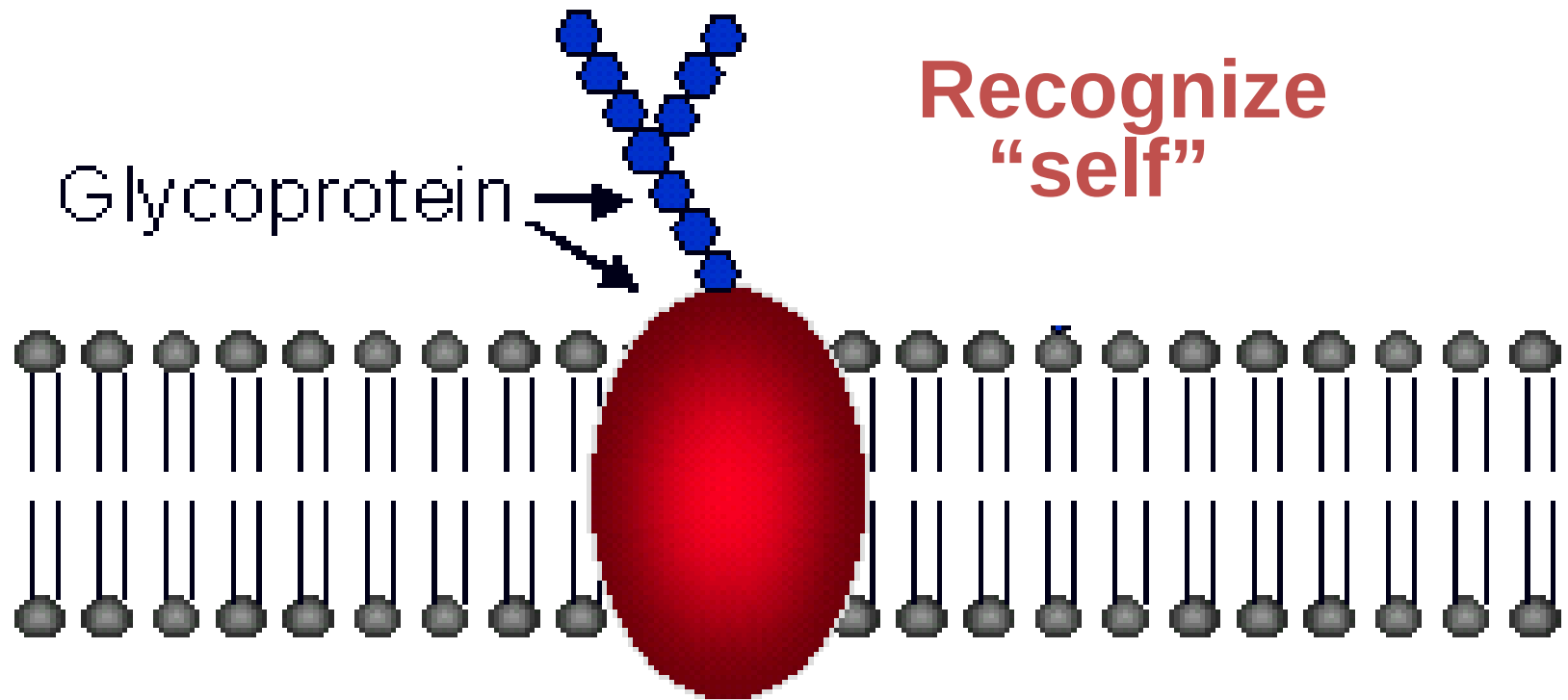


Cell Membrane Proteins

- Proteins **help move large molecules** or aid in **cell recognition**
- **Peripheral proteins** are attached on the surface (inner or outer)
- **Integral proteins** are embedded completely through the membrane



Glycoproteins



Glycoproteins have **carbohydrate tails** to act as markers for cell recognition

Membrane proteins functions

- Passage ways or channels
- Other proteins serve as **carrier molecule that transport specific molecule**
- Many proteins on the outer surface serve as **receptor sites** that recognize and bind with specific molecules in the cell environment
- Another group of proteins **act as membrane-bound enzymes that control specific chemical reactions** on either side of the plasma membrane

Membrane proteins function cont'd

- Some proteins are arranged as filaments network/meshwork on the inner side and are secured to certain internal protein elements of the cytoskeleton
- Other proteins function as **cell adhesion molecules**
- Some proteins, especially in conjunction with carbohydrate are important in the cell's ability to recognize self' and in cell-to-cell interactions.

Functions of biological membranes

1. **As channel protein and carrier protein:** are involved in the selective transport of polar molecule and ion across the membrane
2. **As Enzymes:** membrane proteins sometimes act as enzymes
3. **As receptor molecules:** act as receptor molecules for chemical signaling between cells.
4. **As antigens:** these act as cell identity markers or "name tag". Eg. Glycoproteins
5. **As glycolipids:** act as a receptor sites for chemical signals.
6. **As Energy Transfer in photosynthesis and respiration**
7. **As Cholesterol:** acts like a plug, reducing even further the escape or entry of polar molecules through the membrane.

Ribosomes

- Non-membrane bounded
- Made of **Proteins** and **rRNA**
- Protein factories for cell
- Can be attached to Rough ER or free (unattached) in the **cytoplasm**
- **70S in prokaryotes and 80S in eukaryotes**

Cellular diversity

- Cells are diverse in their **size, shape** and in **their internal structure**
 - This diversity is influenced by their roles and function within organism's body.

Cell Shape

- ❖ Cells have different shapes due to appropriate function.
 - E.g. **Nerve** cells have long extensions.
 - ✓ **Skin** cells have a shape which is flat.
 - ✓ **Egg** cells have shape which is like sphere, and
 - ✓ some **bacteria** are rod in shape.
 - ✓ Some **plant** cells are rectangular

Cell size

- ❖ Some cell can be seen without using magnification instruments as they are enough to be seen by the naked eye.

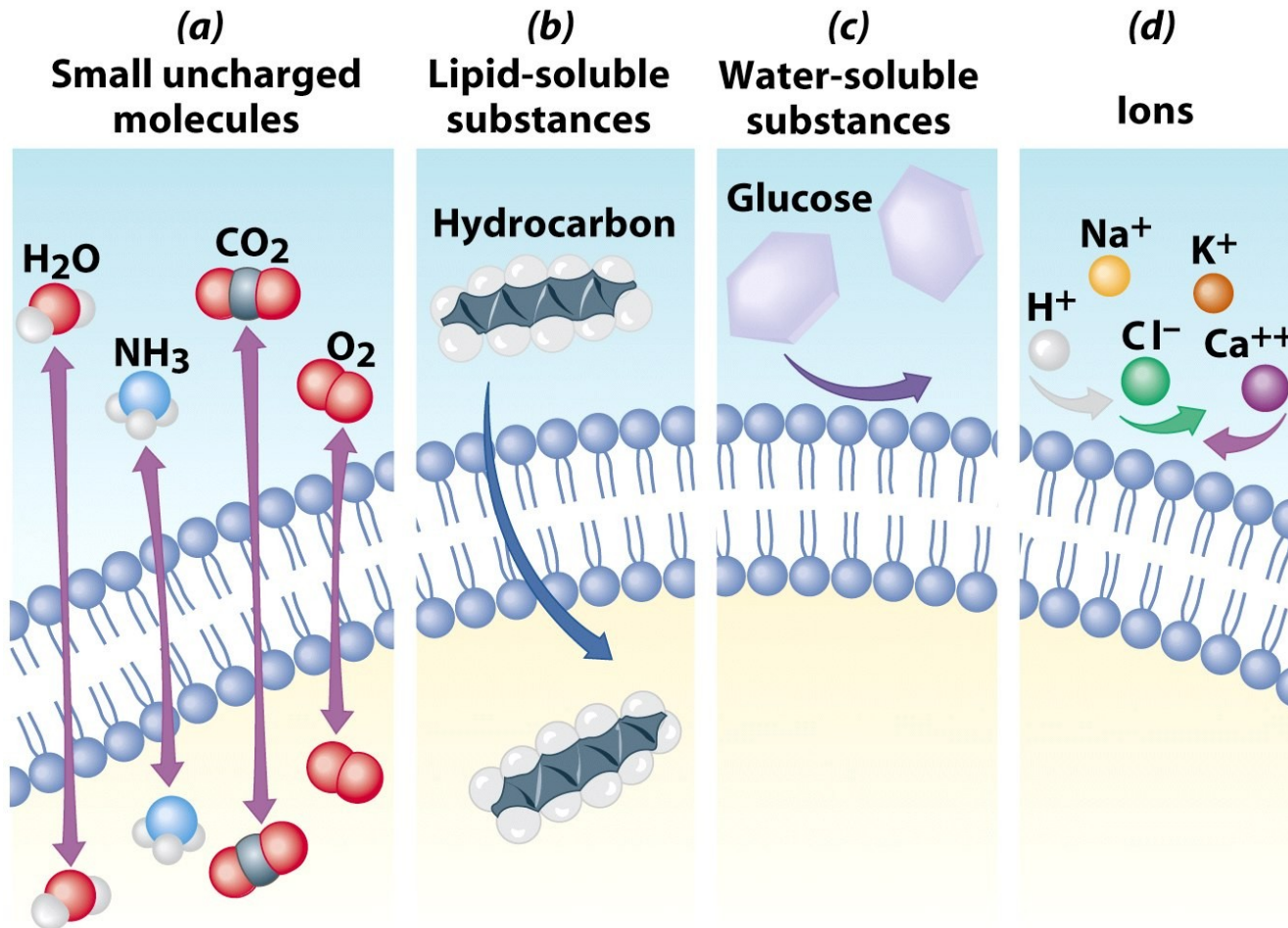
E.g. Egg of birds/reptiles and a neuron cell of giraffe, which is 2 meters in length.

Transport across the cell membranes

- Internal composition of cell is maintained b/c plasma membrane is selectively permeable to small molecules.
- Plasma membrane forms barriers that blocks free exchange of molecules b/n cytoplasm and external environment
- Movement of molecules through cell membrane depends on:
 - **Molecular size, polarity and charge**

Cont'd

- A few molecules move freely
 - Water, Carbon dioxide, Ammonia, Oxygen



Cont'd

- Lipid-soluble substances and small ions can passively diffuse through the plasma membrane down their electro-chemical gradients.
- Highly lipid-soluble particles are able to dissolve in the lipid bilayer and pass through the membrane.
- Uncharged/non-polar molecules oxygen, carbon dioxide and fatty acids are highly lipid-soluble and readily permeate the membrane.

Passive Diffusion

- Simplest mechanism by which molecules can cross plasma membrane
- No membrane proteins are involved and direction of transport is determined by molecule concentration
- Molecules able to dissolve in phospholipid bilayer can cross CM by diffusion
- **E.g. Gases such as O_2 and CO_2 , hydrophobic molecules (eg. Benzene) and small polar but uncharged molecules (such as water and ethanol) are able to diffuse across plasma membrane**

❖ **Diffusion** is the net movement of molecules (or ions) from a region of their high concentration to a region of their lower concentration.

✓ The molecules move down a concentration gradient.

The factors that influence the rate of net diffusion across a membrane are:

1. permeability of the membrane
2. surface area of the membrane
3. molecular weight of the substance (lighter one diffuses rapidly)
4. distance through which diffusion must take place

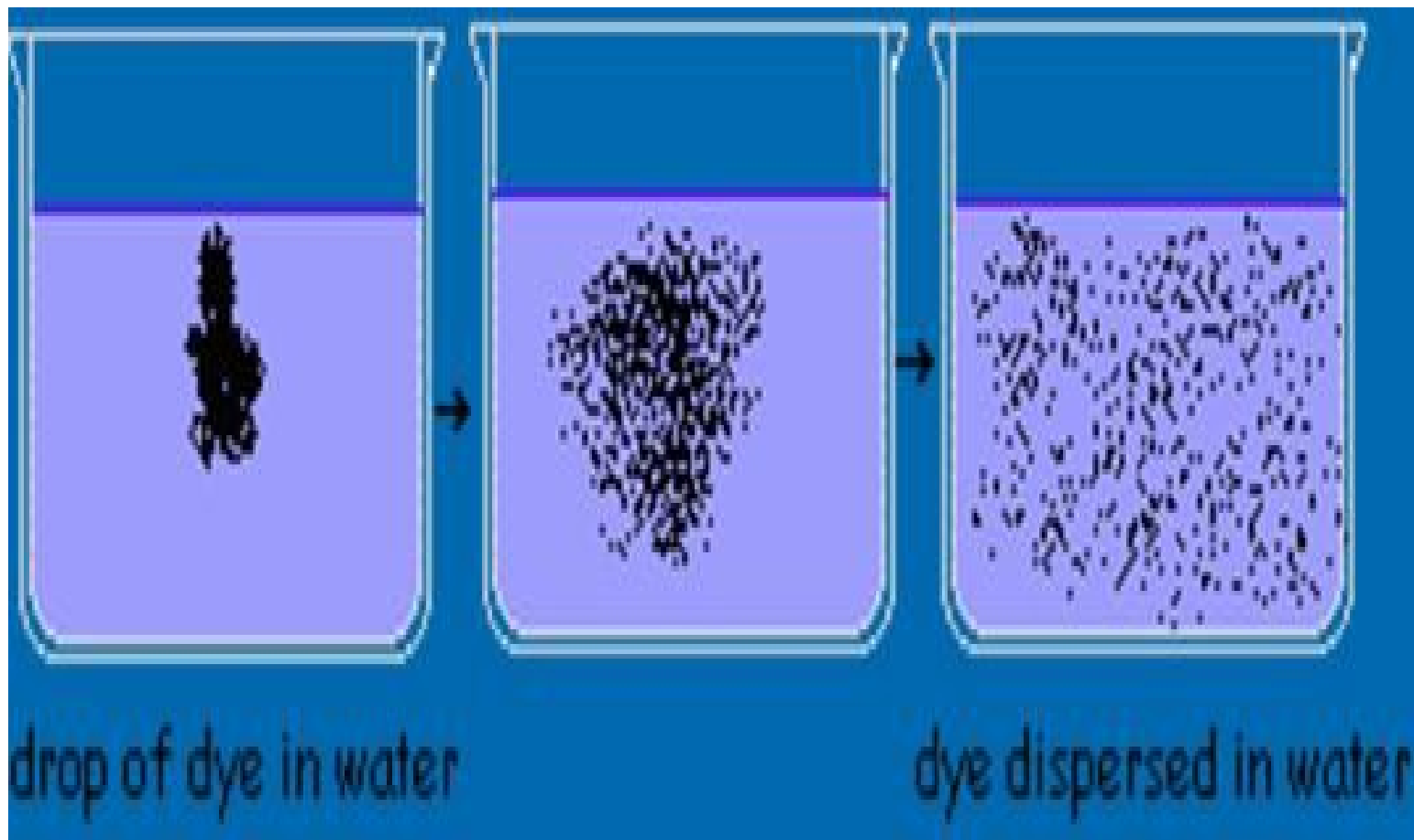


Fig. 5: Diffusion of molecules

2. Osmosis

- It is the net diffusion of water down its own concentration gradient.
- Water can readily permeate the plasma membrane.
- from area of higher water concentration (low solute) to the area of lower water (high solute) concentration.
- It is net diffusion of water

3. Facilitated Diffusion

- ❖ **Facilitated diffusion** uses **carrier proteins/channel proteins** to facilitate the transfer of a particular substance across the membrane "downhill" from higher to lower concentration.
- ✓ This process is **passive** and **does not require energy** because movement occurs naturally
- ✓ Transported molecules **do not dissolve in phospholipid bilayer**, instead their passage **mediate by proteins that enable the transported molecules** to cross without interacting with its hydrophobic interior.
- ✓ **Allows polar and charged molecules such as carbohydrates, amino acids, nucleosides and ions to cross the plasma membrane**

❖ **Carrier proteins** binds specific molecules to be transported on one side of the membrane.

✓ And then undergo conformational change that allows molecules to pass through the membrane.

❖ **Channel proteins** simply form **open pores** in the membrane, allowing small molecules of appropriate size and charge to pass freely through lipid bilayer.

❖ **Carrier mediated transport** displays three characteristics

- **Specificity**: each cell possesses protein specified to transport a specific substance
- **Saturation**: in a given time only a limited amount of a substance can be transported via a carrier (transport maximum(T_m))
 - ✓ T_m is reached, the carrier is saturated, and the rate of transport is maximum
- **Competition**: Several closely related compounds may compete for ride across the plasma membrane on the same carrier

4. Active transport

- ❖ **Energy consuming transport of molecules** or ions across a membrane against its natural tendency to diffuse in the opposite direction.
- ❖ The movement of molecules in active transport is in one direction only.
- ❖ Uses energy derived from **ATP** hydrolysis to transport Na^+ and K^+ against concentration gradient

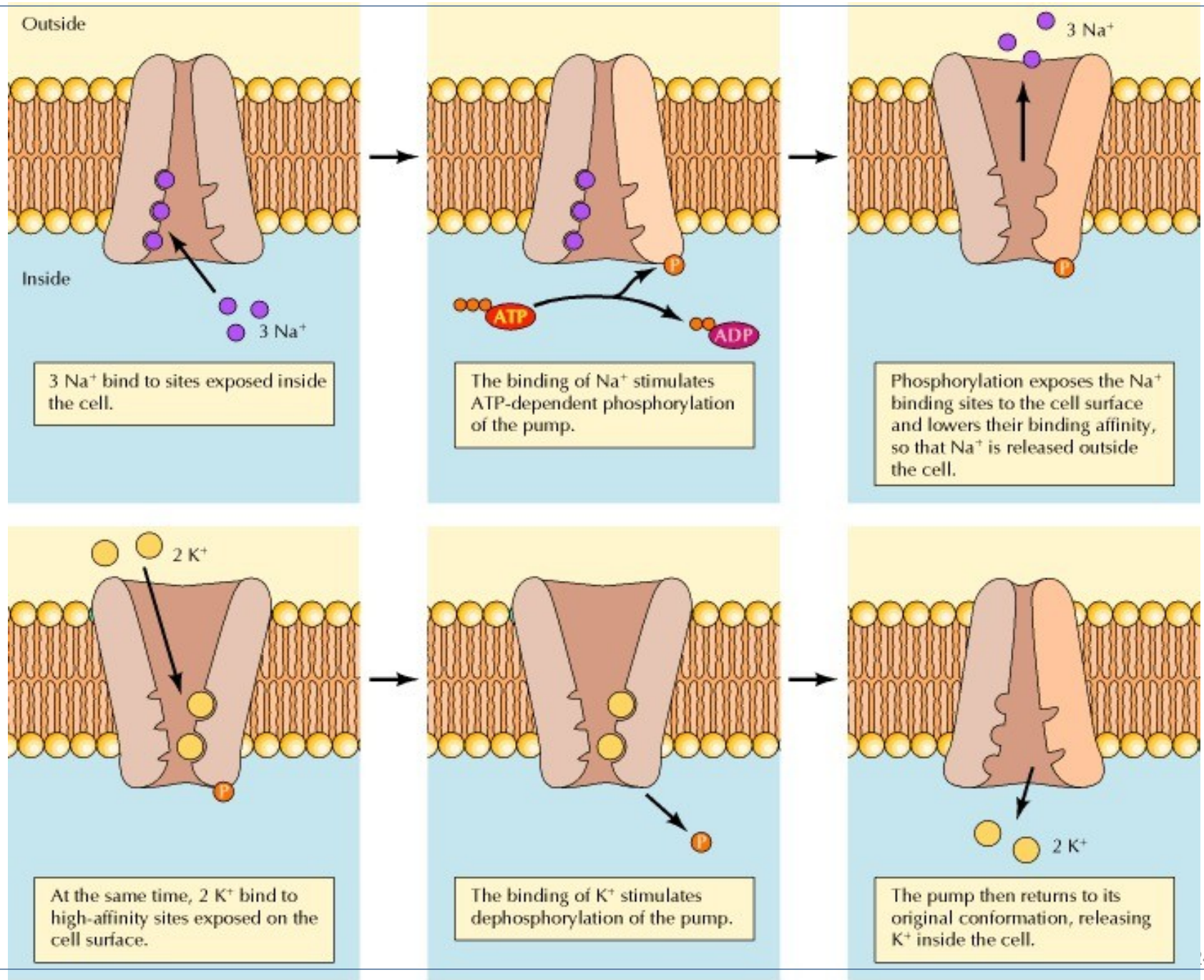
Na^+ - K^+ -pump

Cont'd

- The major ions within the cells and their surrounding are sodium (Na^+), potassium (K^+) and chloride (Cl^-).
- Most cell have sodium pump is coupled with a potassium pump that actively moves **potassium ion from outside to inside the cell**. The combined pump is called the sodium pump ($\text{Na}^+\text{-K}^+$ pump).
- The pump is a carrier protein that spans across the membrane from one side to the other

Na⁺-K⁺-pump plays three important roles

1. It establishes sodium and potassium concentration gradients across the plasma membrane of all cells.
2. It helps regulate cell volume by controlling the concentration of solutes inside the cell.
3. Serves as the energy source for the co-transport of glucose and amino acids across the membrane (intestine and kidney cell).



How molecules cross cell membrane

	Active/ Passive	Molecules that Move	Direction	Energy Needed?	Protein Needed?
Diffusion	Passive	small, hydrophobic	<u>down</u> gradient (toward low conc.)	no	no
Osmosis	Passive	water	toward high conc. of <u>solutes</u>	no	no
Facilitated Diffusion	Passive	any (specific transporter)	<u>down</u> gradient (toward low cons.)	no	yes
Active Transport	Active	any (specific transporter)	specific: in <u>or</u> out, dep. on transporter	yes	yes

4. Bulk Transport

- Cells also need to **remove** and **take in larger molecules and particles**
- **Large particle**, however, cannot pass through the membrane, even with energy supplied by the cell.
- Some cells are even capable of engulfing entire unicellular microorganisms
- **Transport into the cell** is termed **endocytosis**, whereas **transport out of the cell** is called **exocytosis**.
- Endocytosis and exocytosis are active processes involving the bulk transport of materials through membranes.

Endocytosis

- Type of active transport that moves particles, such as large molecules, parts of cells, and even whole cells, into a cell.
- **In endocytosis**, plasma membrane of the cell invaginates, forming a pocket around the target particle.
- The pocket pinches off, resulting in the particle being contained in a newly created intracellular vesicle formed from the plasma membrane.
- There are different variations of endocytosis
 - ✓ **Phagocytosis, Pinocytosis and Receptor-mediated endocytosis**

Endocytosis cont'd

- **Endocytosis** occurs by an in folding or extension of cell surface membrane to form a vesicle or vacuole.
 - **Phagocytosis** (cell eating) material taken up is in solid form.
 - **Pinocytosis** (cell drink) material taken up is in liquid form- endocytosis of fluid
 - **Receptor-mediated Endocytosis**- employs receptor proteins in the plasma membrane that have a specific binding affinity for certain substances

Exocytosis

- Is reverse process of endocytosis
- Purpose is to expel material from the cell into the extracellular fluid
- Waste material is enveloped in a membrane and fuses with the interior of the plasma membrane
- This fusion opens the membranous envelope on the exterior of the cell, and the waste material is expelled into the extracellular space

3.4. Cellular respiration

Learning competencies

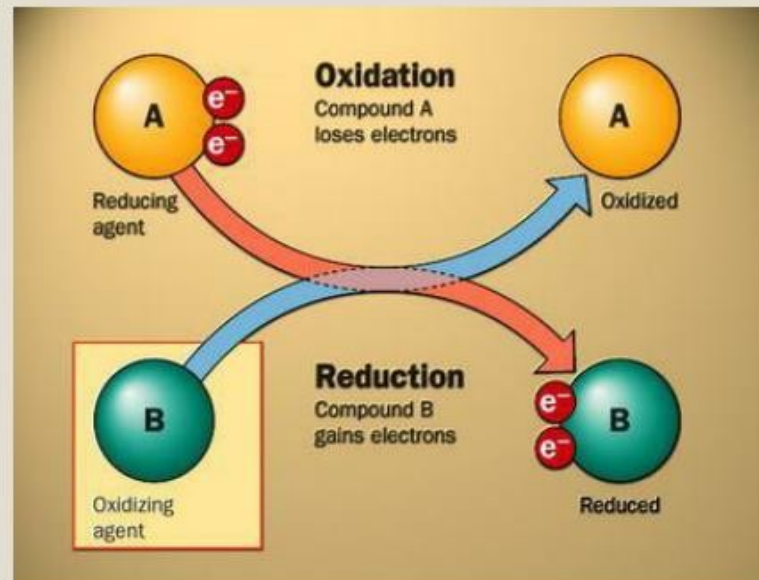
- Describe the structure of ATP and its role in cellular metabolism.
- Explain how ATP is adapted to its role as an energy transfer molecule within a cell.
- Describe how ATP is produced in a cell.
- Locate where the different processes of cellular respiration occur in the cell.
- Explain the role of electron donors and acceptors.
- Describe in detail each stage of aerobic respiration.
- Draw and label the structure of a mitochondrion.
- Explain the processes of alcoholic fermentation and lactate production.
- Appreciate the importance of lactate production during running and other sports.
- Summarise the metabolism of proteins, polysaccharides and lipids.

Cell Respiration

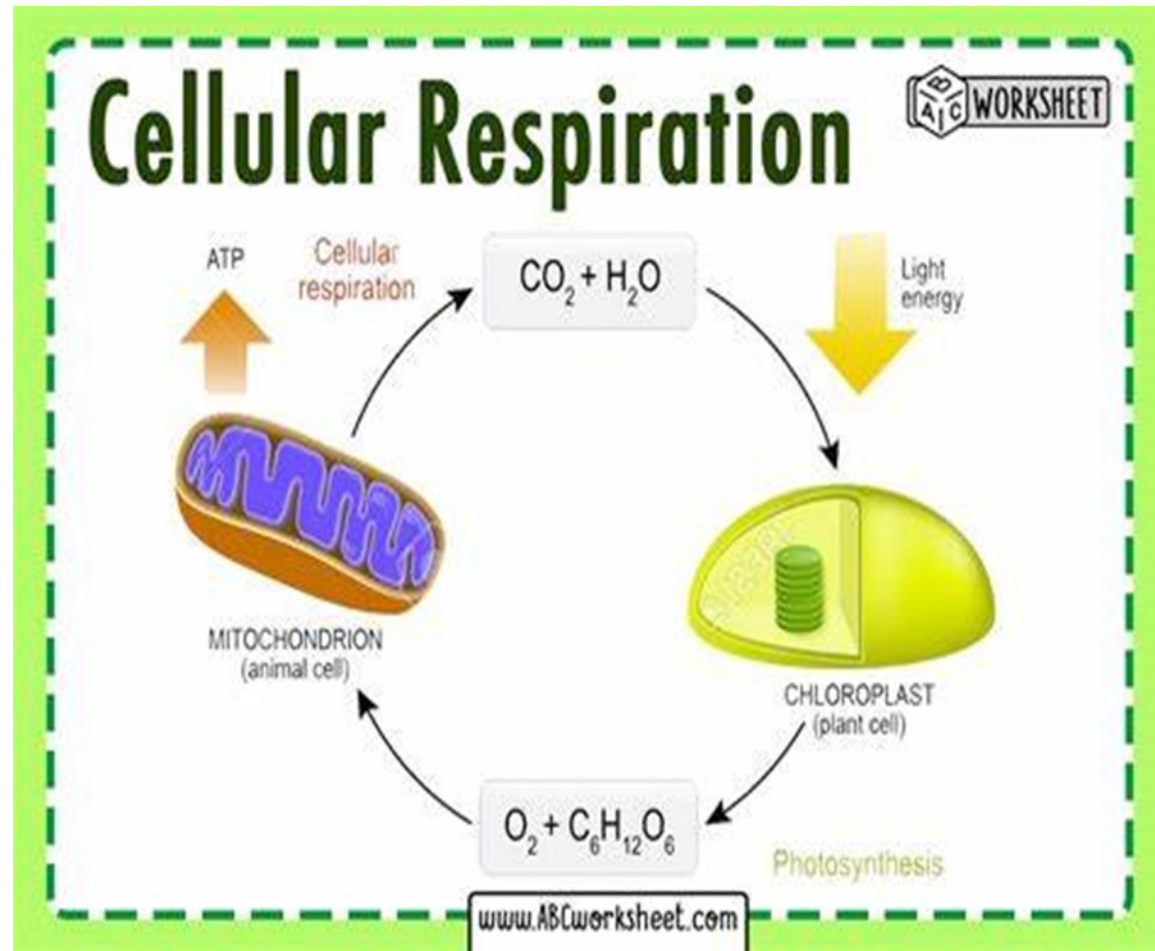
- To understand cellular respiration, we first need to understand the processes of oxidation and reduction.

OIL RIG : OXIDATION IS LOSS, REDUCTION IS GAIN

- Oxidation = loss of electrons (increase in oxidation #)
ex: $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^{-}$
- Reduction = gain of electrons (decrease in oxidation #)
ex: $\text{S} + 2\text{e}^{-} \rightarrow \text{S}^{2-}$



- **CR:** chemical process that releases energy from organic compounds (food), gradually converting it into energy that is stored in ATP molecules



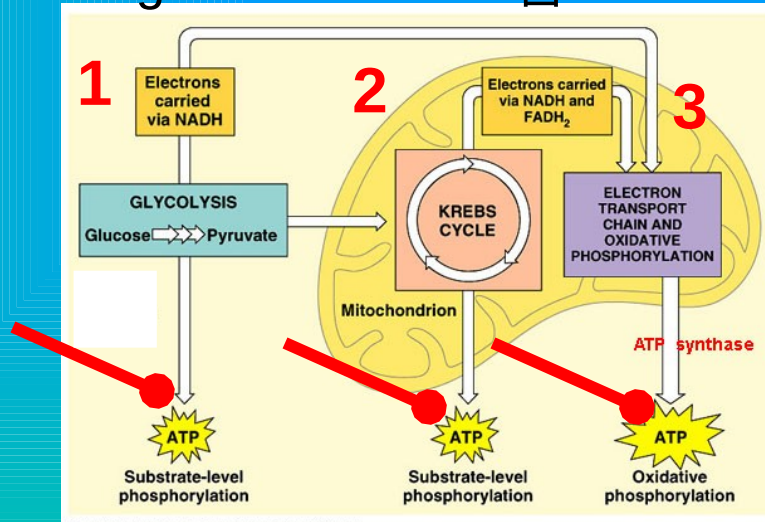
– All three combined make up Cellular Respiration: Glycolysis + Krebs Cycle + Electron Transport Chain

- Process that releases energy by breaking down food molecules in the presence of oxygen

Equation for cellular respiration:



oxygen + glucose $\longrightarrow$ carbon dioxide + water + energy



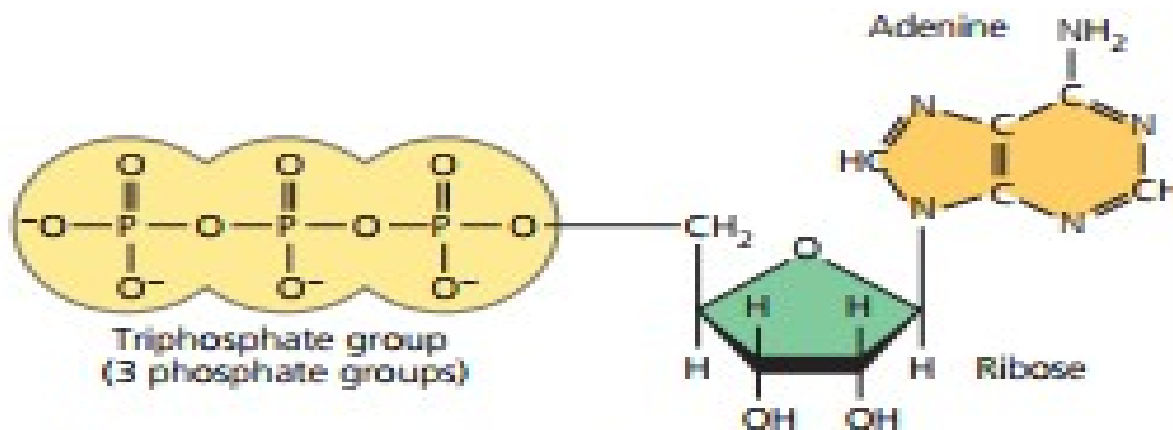
Each of these 3 stages captures some of the chemical energy available in food molecules and uses it to produce ATP

Cont...

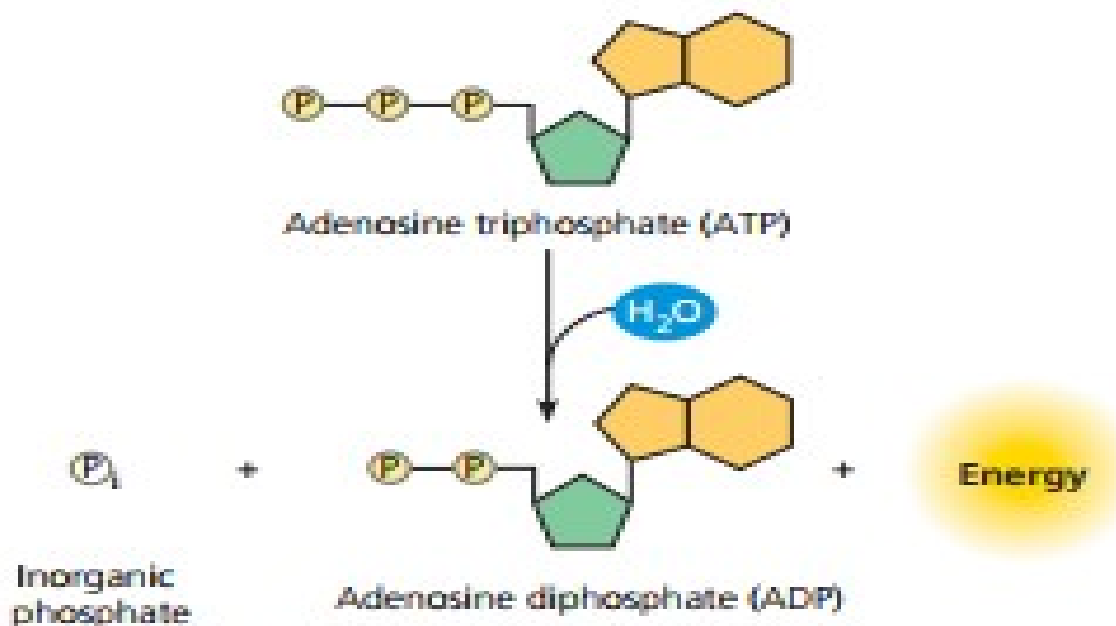
- Most living organisms obtain energy by breaking down organic molecules (**catabolism**) during cellular respiration.
- The function of cellular respiration is to harvest electrons from carbon compounds, such as glucose and to make Adenosine Triphosphate (ATP).
- Cellular respiration occurs in **two** main parts:
 1. **Glycolysis** :- is an anaerobic process.
 - do not require oxygen.
 2. **Aerobic respiration**:- it includes the **Krebs cycle** and **electron transport chain** which require oxygen.

1. Glycolysis

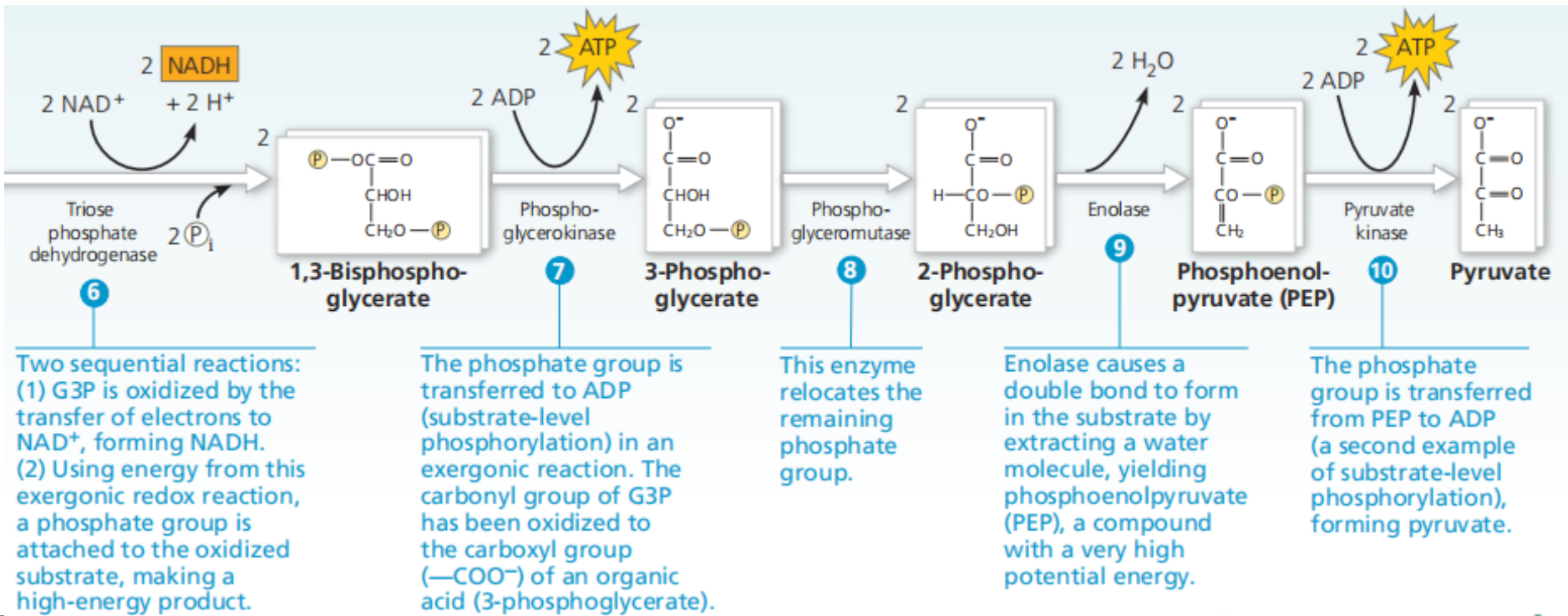
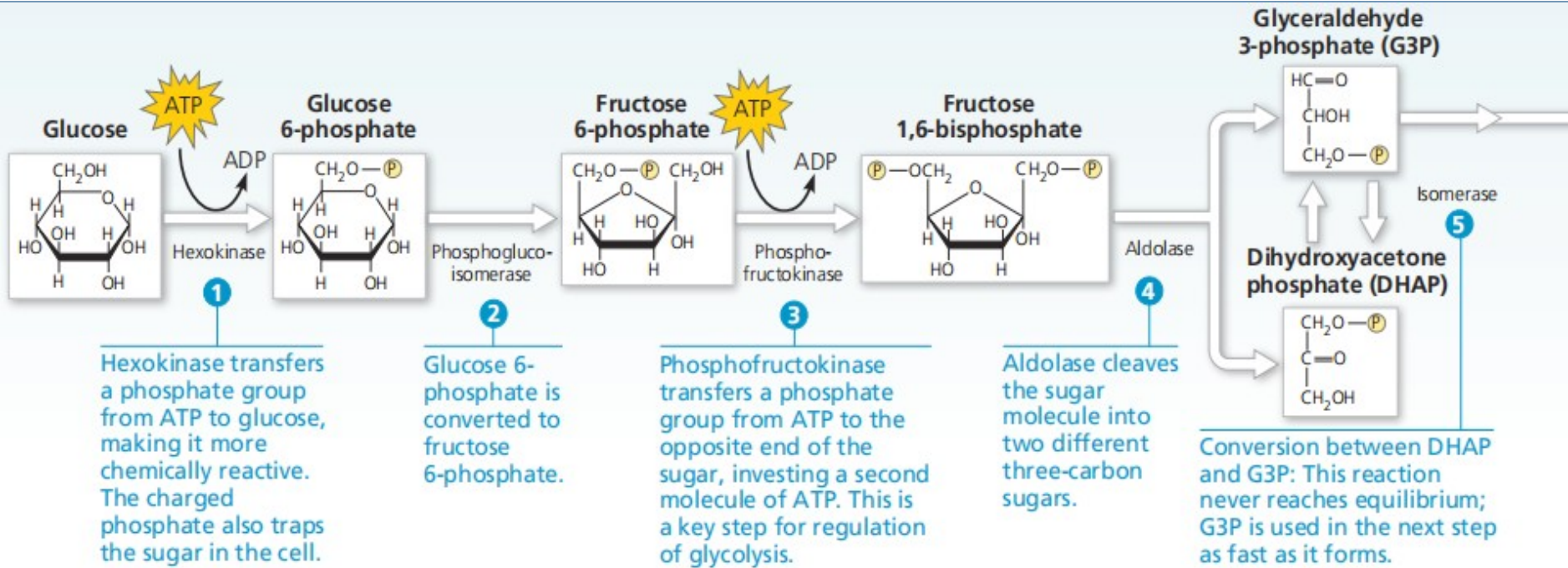
- Is the process of **degradation of glucose**, which breaks down glucose to **pyruvate**.
- The main purpose of glycolysis is the **generation of energy (ATP)**.
 - ✓ but much more ATP is formed downstream of glycolysis **through the complete oxidation of pyruvate**.
- Found in animals, plants and microorganisms.
- **Used by anaerobic as well as aerobic organisms.**
- The process takes place in the **cytoplasm** of prokaryotes and eukaryotes



(a) The structure of ATP. In the cell, most hydroxyl groups of phosphates are ionized (—O^-).



(b) The hydrolysis of ATP. The reaction of ATP and water yields inorganic phosphate (P_i) and ADP and releases energy.



❖ It involves **ten enzymatic reactions** as described below:

1. The phosphorylation of glucose at carbon-6 by **hexokinase** forming glucose 6-phosphate (G6P).
2. The conversion of glucose-6-phosphate(G6P) to fructose-6-phosphate(F6P) by **phosphohexose isomerase**
3. The phosphorylation of fructose-6-phosphate to the 1,6-bisphosphate by **phospho-fructokinase**
4. The cleavage of fructose-1,6-bisphosphate by **aldolase**. This yields two different products, **dihydroxyacetone phosphate** and **glyceraldehyde-3-phosphate**

5. The isomerization of **dihydroxyacetone phosphate** to a second molecule of **glyceraldehyde-3-phosphate** by **triose phosphate isomerase**
6. The dehydrogenation and concomitant phosphorylation of glyceraldehyde-3-phosphate to 1,3-bis-phosphoglycerate by **glyceraldehyde-3-phosphate dehydrogenase**
7. The transfer of the 1-phosphate group from 1,3-bis-phosphoglycerate to ADP by **phosphoglycerate kinase**, which yields ATP and 3-phosphoglycerate

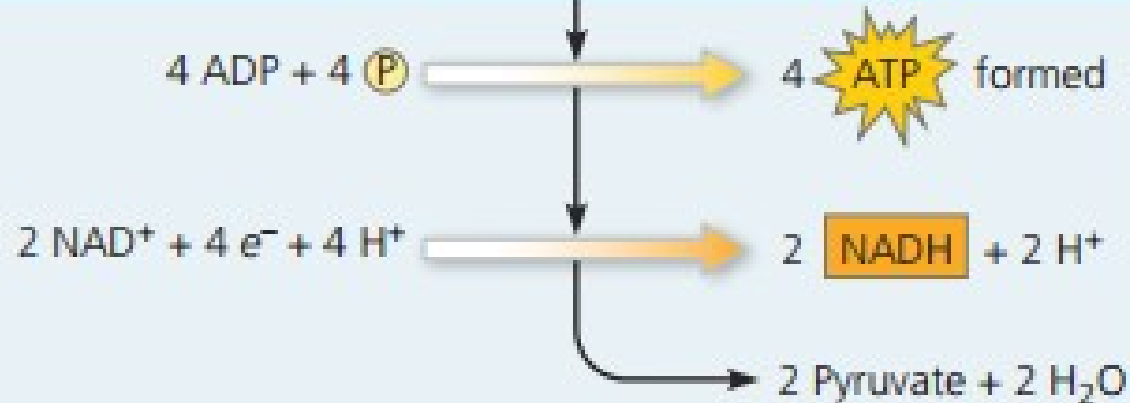
8. The isomerization of 3-phosphoglycerate to 2-phosphoglycerate by **phosphoglycerate mutase** (PGAM)
9. The dehydration of 2-phosphoglycerate to phosphoenolpyruvate by **enolase**.
10. The transfer of the phosphate group from phosphoenolpyruvate to ADP by **pyruvate kinase**, to yield a second molecule of ATP.

GLYCOLYSIS:

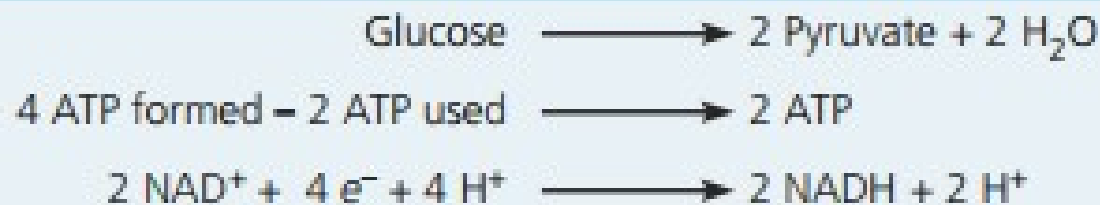
Energy Investment Phase



Energy Payoff Phase



Net Inputs and Outputs



TCA cycle and ETC: Aerobic respiration

- One fate of pyruvate enters TCA cycle is to complete oxidation.
- But there are intermediate processes that convert pyruvate to a acetyl coA.
- The enzyme complex converts pyruvate into Acetyl-CoA by the following chemical changes:
 - ✓ **Decarboxylation of pyruvate (loss of CO_2)**
 - ✓ **Formation of acetyl group**
 - ✓ **Linkage of acetyl group to coenzyme A forming acetyl - CoA.**

2. The Tricarboxylic Acid (TCA) Cycle

- Prior to the Krebs cycle, **pyruvate** reacts with **coenzyme A** (CoA) to form a 2-carbon intermediate called **acetyl CoA**.
- At the same time, carbon dioxide is released and **NAD** is converted to **NADH**
- Acetyl CoA then moves to the mitochondrial matrix. The reaction results in the production of **two carbon dioxide** molecules and **two NADH**.

Krebs cycle cont'd

- ❖ The TCA cycle also called **Krebs** or **Citric acid cycle**, is considered as central pathway of aerobic metabolism
- ❖ It serves for two purposes-**bioenergetics** and **biosynthesis**

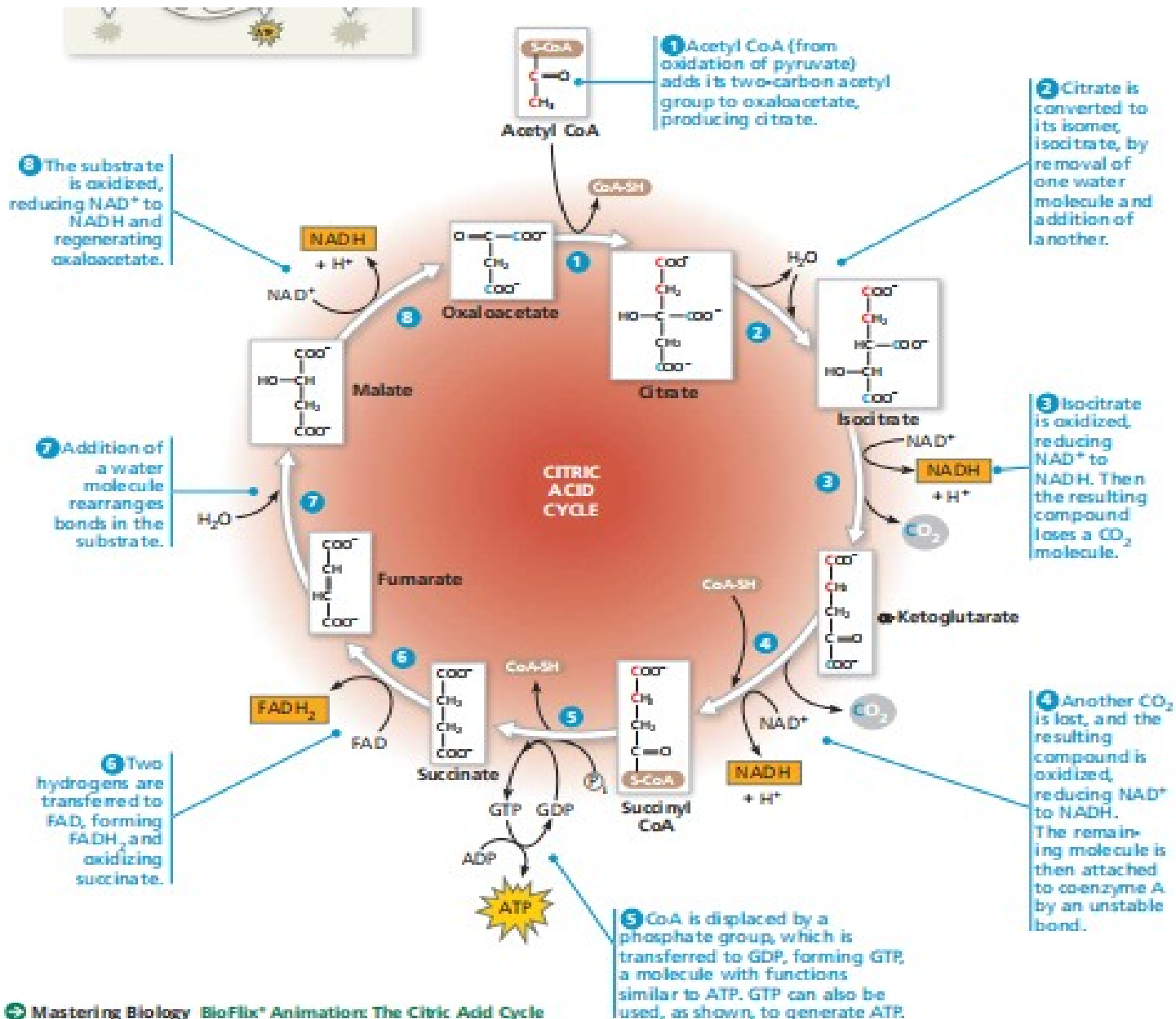
1. Bioenergetic:

- The cycle carries out complex degradation of acetyl group in acetyl - CoA to CO_2 , resulting in release of energy (ATP or GTP) and reducing power (NADH and FADH_2).

2. Biosynthesis: - It supplies precursors for several biosynthetic pathways of amino acids, pyrimidines, purines etc.

Krebs cycle cont'd

- The Krebs cycle begins with **acetyl CoA** combining with a **4-carbon** compound to form a 6-carbon compound known as **citric acid**.
- Citric acid is then broken down in the next series of steps, releasing **2CO₂** and generating **one ATP**, **three NADH**, and **one FADH₂ from single cycle**.
- Finally, acetyl CoA and citric acid are generated and the cycle continues.



Krebs cycle cont'd

2. Biosynthesis: - It supplies precursors for several biosynthetic pathways.

- TCA cycle is also an important source of biosynthetic precursors
 - ✓ α -ketoglutarate and oxaloacetate are used for synthesis of a number of amino acids like glutamic acid, aspartic acid
 - ✓ Succinyl - CoA is used to form porphyrin ring of cytochromes, chlorophyll
 - ✓ Oxaloacetate can also be converted to phosphoenolpyruvate, which is a precursor of glucose.
 - ✓ Acetyl - CoA is the starting material for fatty acid biosynthesis.

Electron Transport Chain

- ❖ It is the final step in the break-down of glucose and point at which **most of the ATP is produced.**
- ❖ Process by which **ATP synthase** phosphorylate **ADP** into **ATP** in electron transport chain is **oxidative phosphorylation**
- ❖ **Oxygen is the final electron acceptor** in **ETC.**
- ❖ **Protons** and **electrons** are **transferred to oxygen** to form **water.**
- ❖ Occurs within the **cell membrane of bacteria/** in **inner membrane of mitochondria of eukaryotic** organisms

ETC cont'd

- Energy in the form of electrons released in stepwise from reduced energy carrier molecules
- The **NADH** formed during **glycolysis**, and the **NADH** and **FADH₂** molecules formed in **Krebs cycle** are used to **reduce oxygen** and generate **high energy ATP** molecule.
- ATP is generated from the **oxidation** of **NADH** and **FADH₂** and the subsequent transfer of electrons and pumping of protons
- Pumping of protons powered by electron transport with O₂ as terminal electron acceptor yield ATP

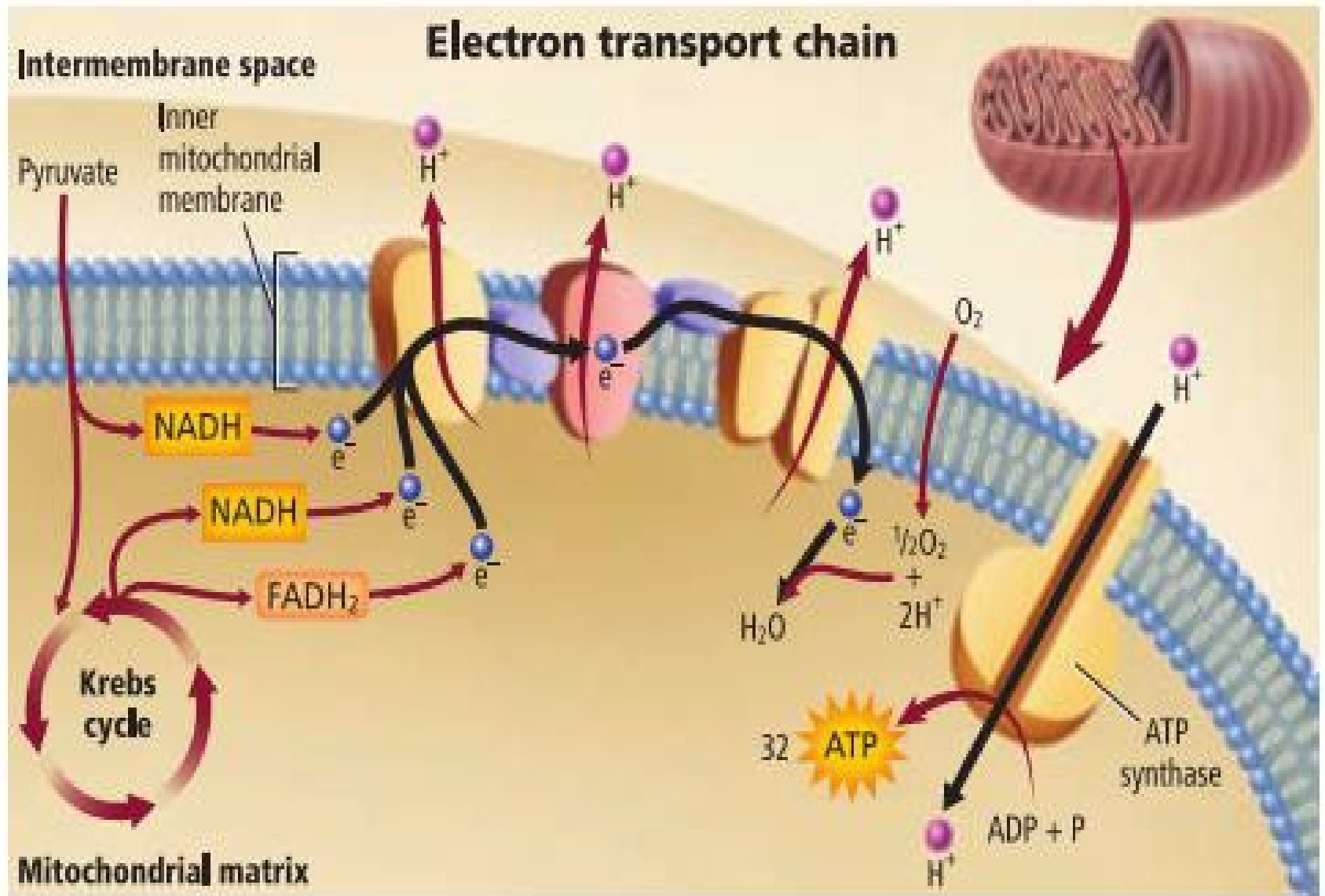
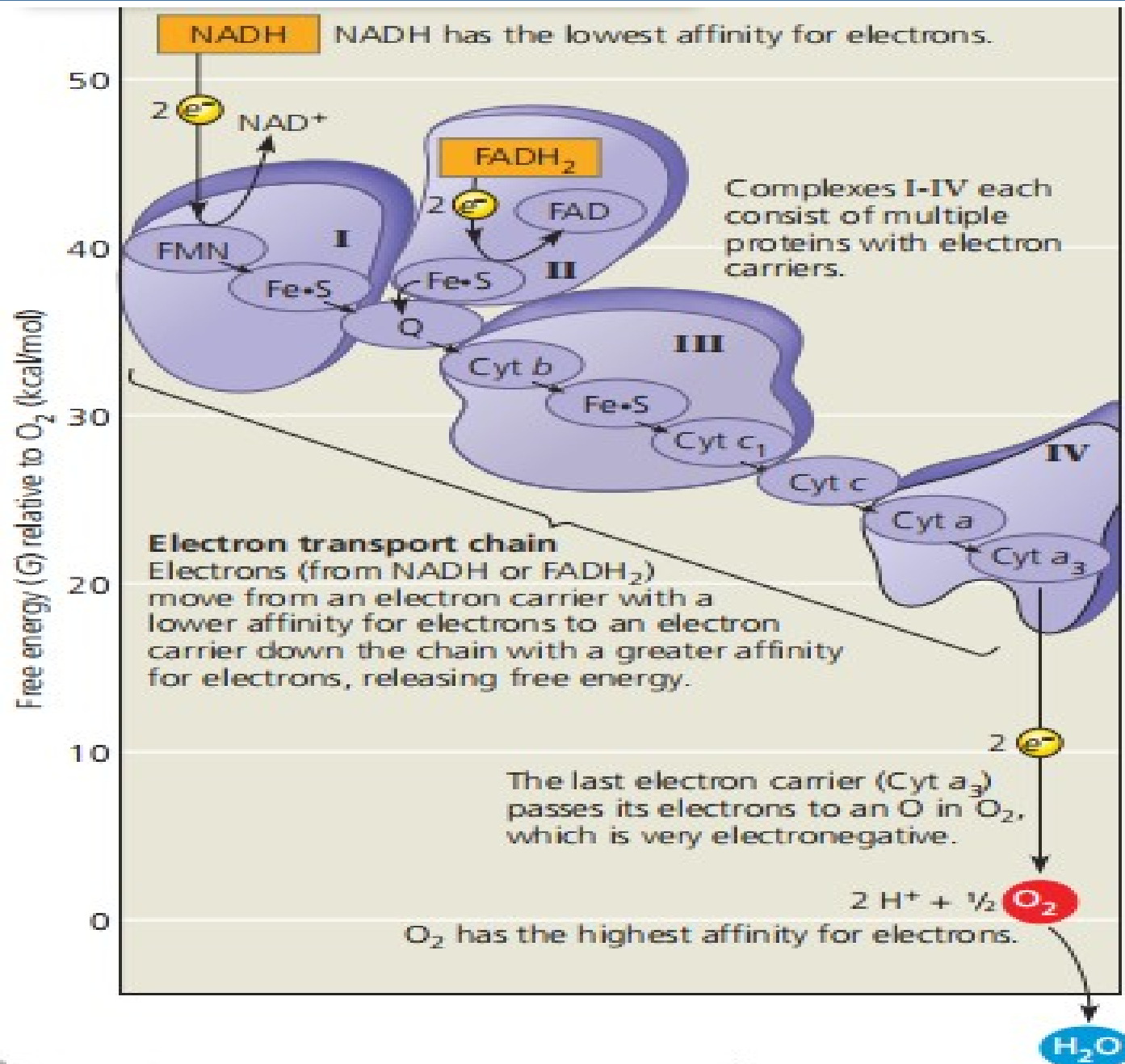
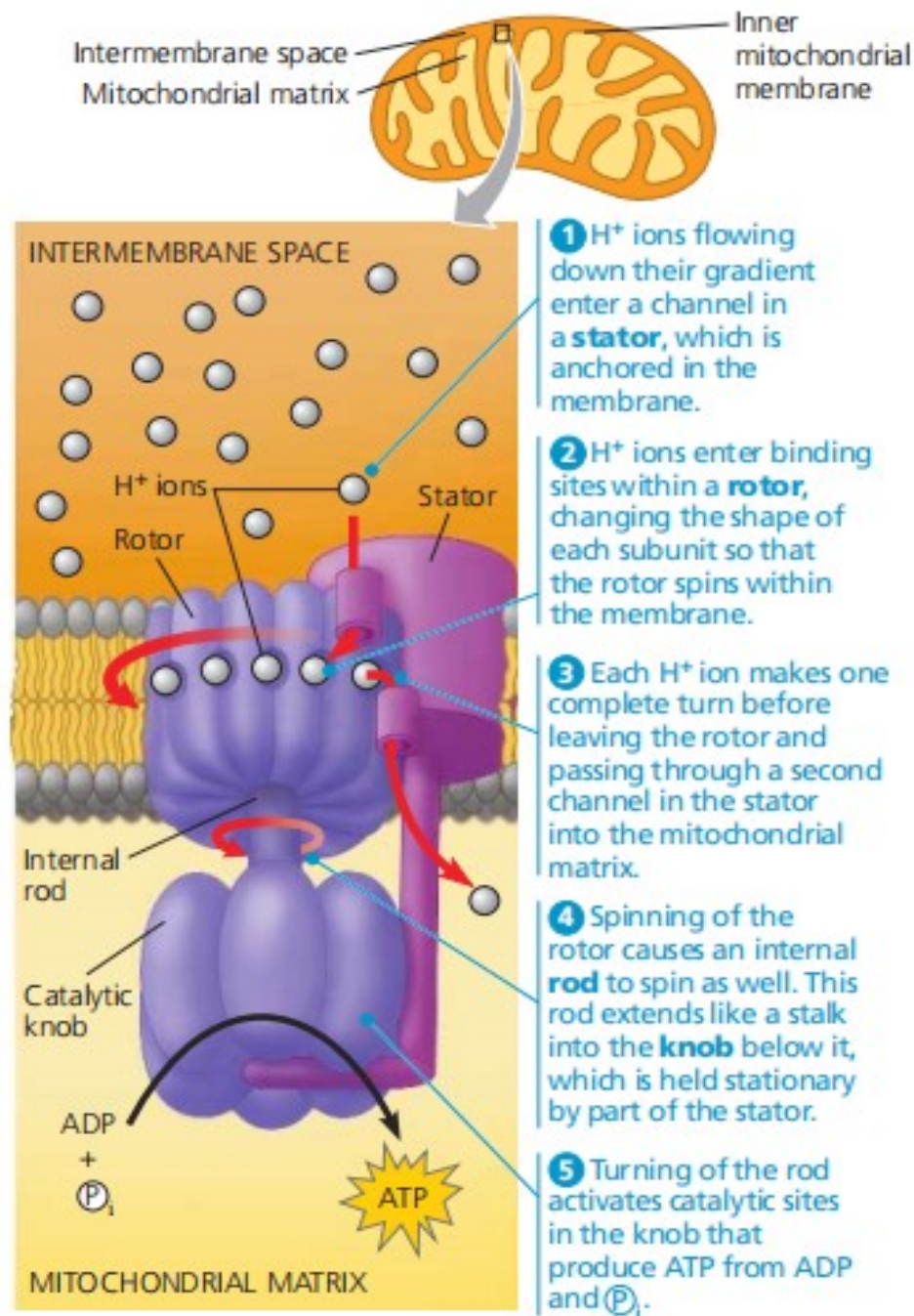


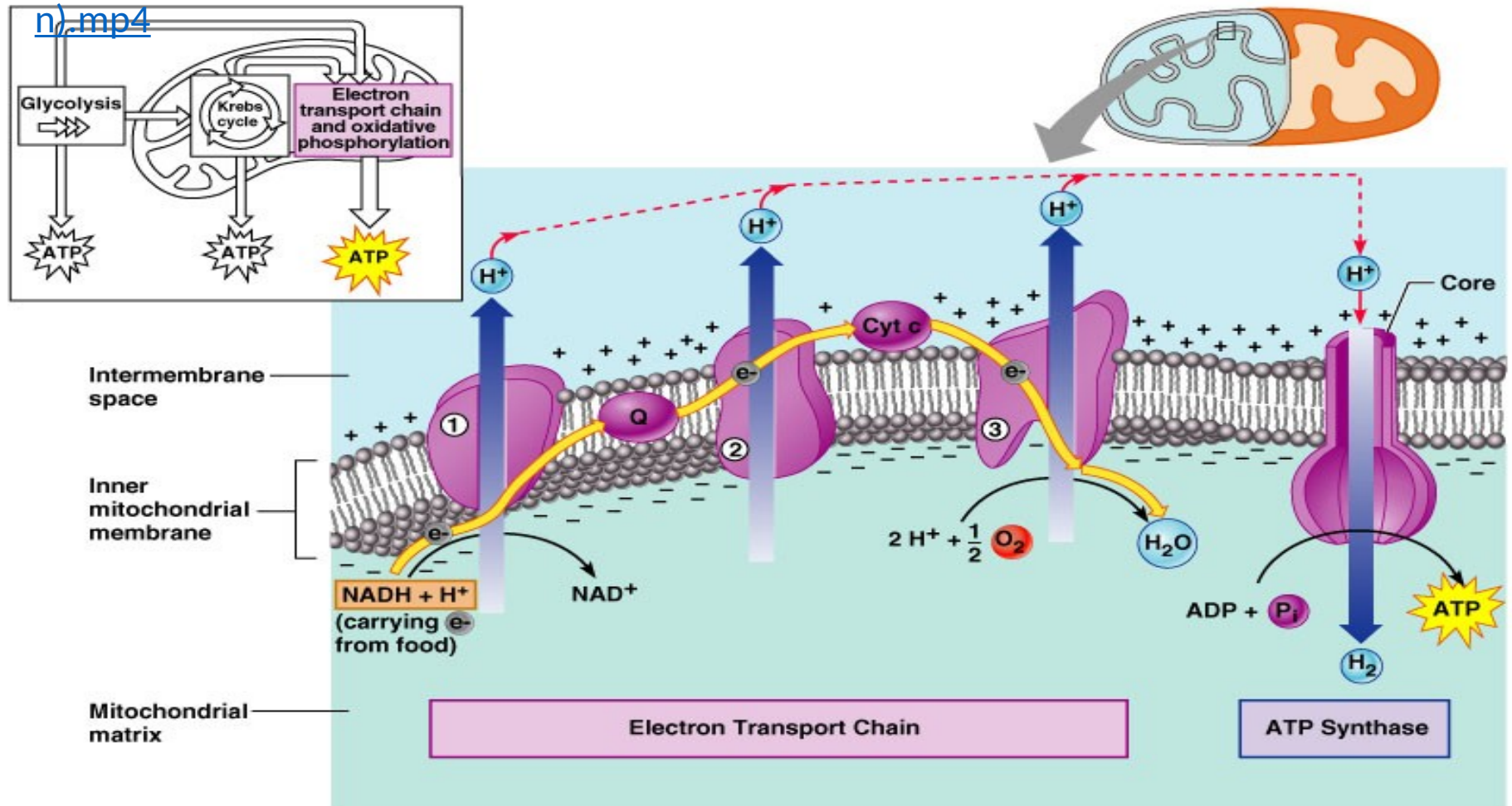
Fig: Electron Transport Chain





Video link:

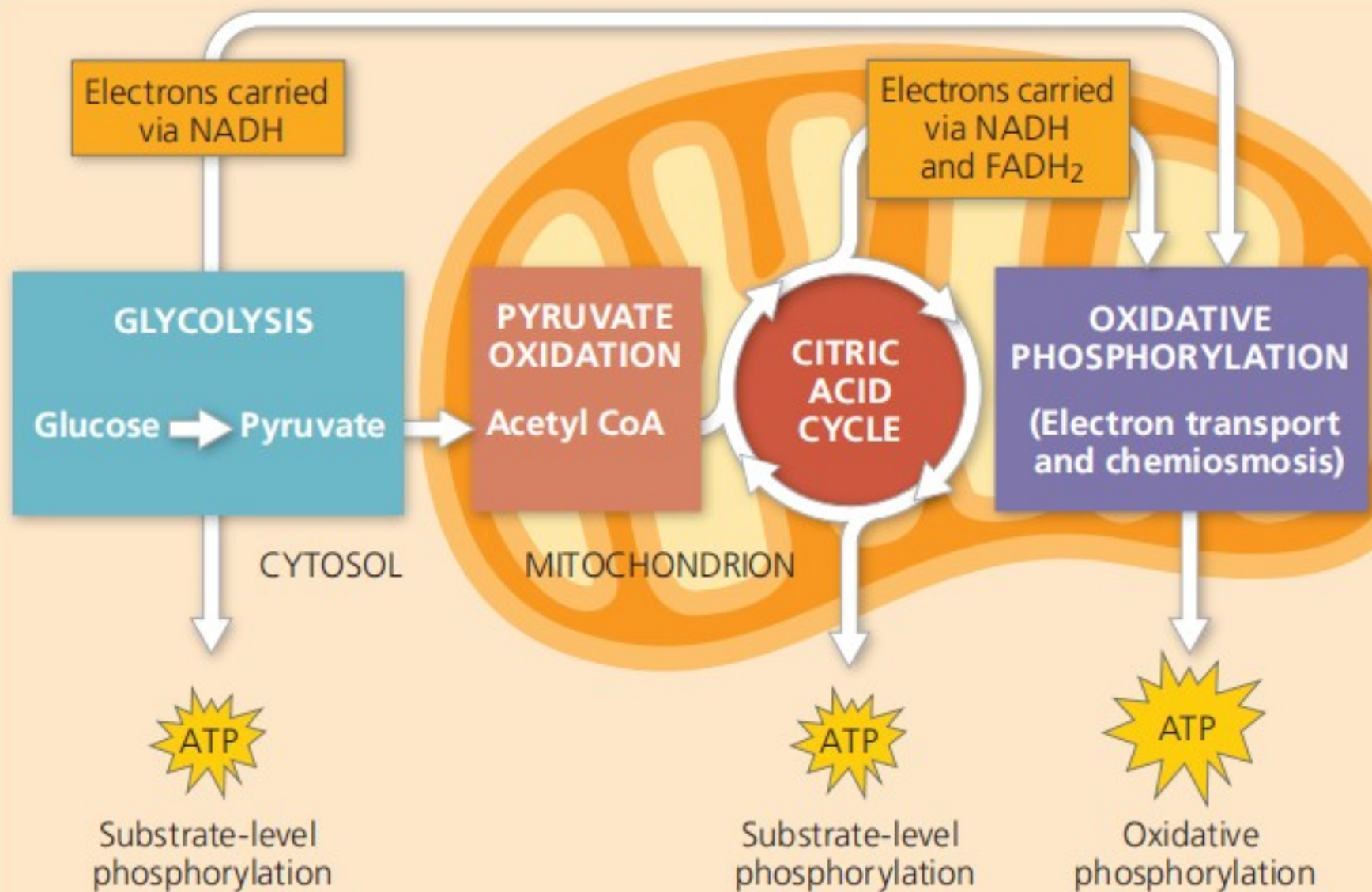
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Chemiosmosis

Electrons are transferred from complex to complex and some of their energy is used to pump protons (H^+) into the intermembrane space, creating a proton gradient.

ATP synthesis is powered by the flow of H^+ back across the inner mitochondrial membrane through ATP synthase.



Unit 4: Microorganisms

- **4.1. Introduction to microorganisms**
- **4.2. Beneficial microorganisms**
- **4.3 Pathogenic microorganisms**

