

Cells

The human body is made up of many different types of cells, which are organised in different sorts of tissues. These tissues are arranged into organs, which make up the different systems of the body. In this way the body is able to perform the different functions necessary for life.

Essentially all animal cells consist of a plasma membrane which contains the cytoplasm, cytosol (cell fluid) plus the organelles. Each of these specialised organelles performs a specific function.

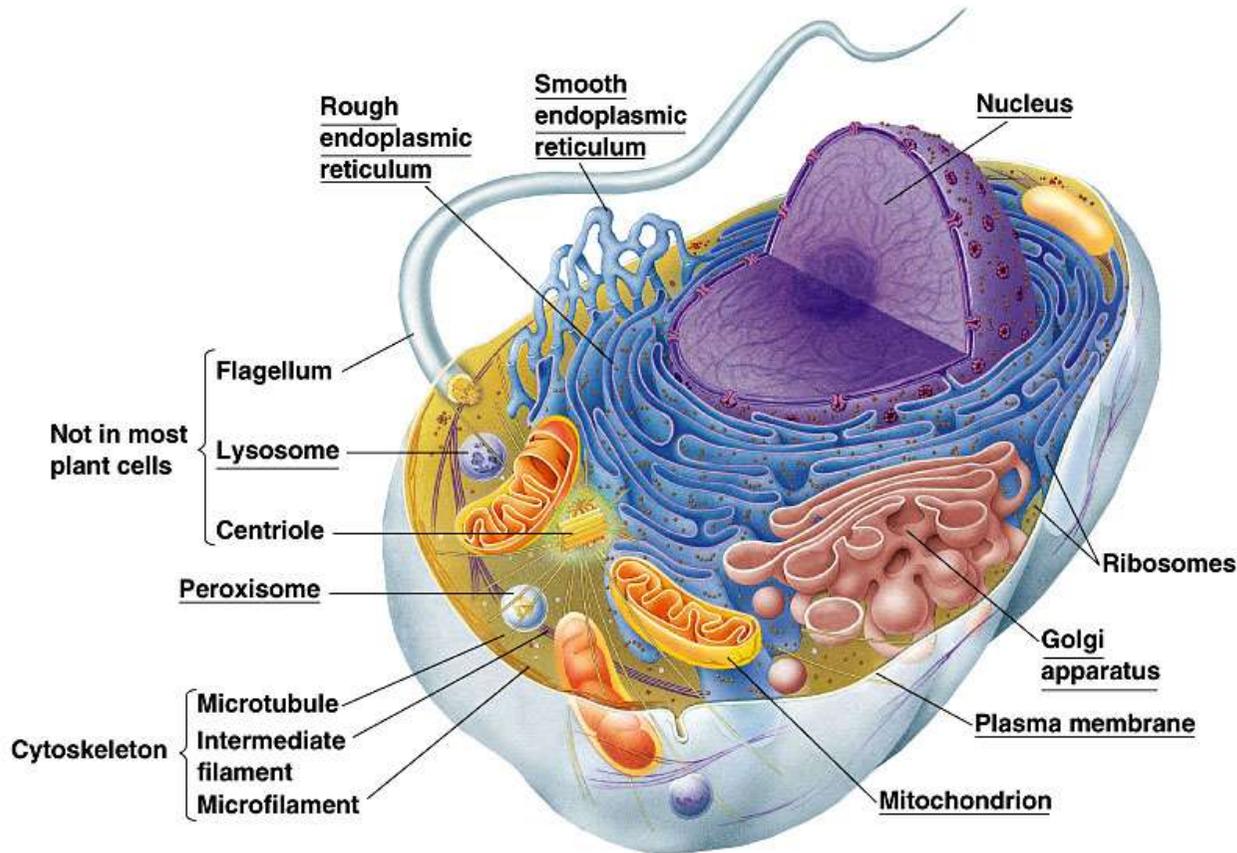


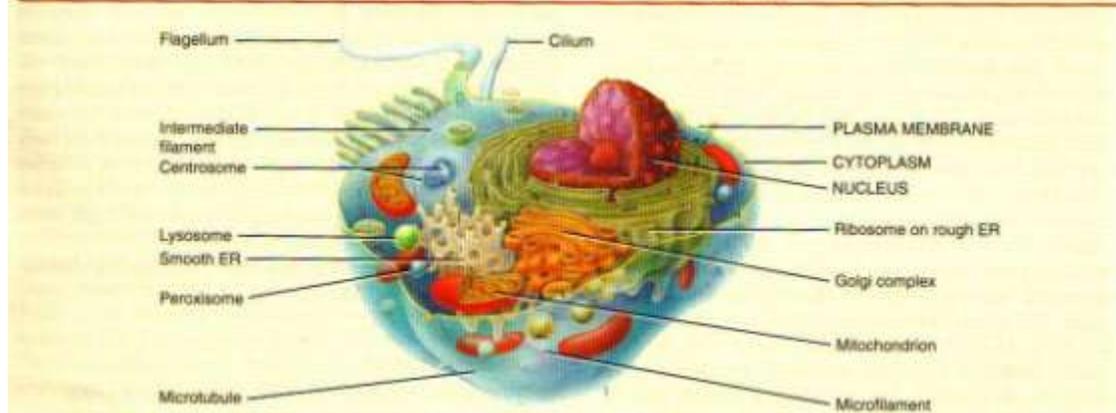
Figure 1 - Typical cell

The plasma membrane consists of phospholipids (or fats), cholesterol and also has proteins embedded in it. The outer and inner surfaces of the membrane have different electrical charges, which helps the passage of different chemicals in and out of the cell. The outer surface is hydrophilic - it attracts water and the inner surface is hydrophobic - it repels water. The proteins are necessary for the passage of some larger molecules in and out of the cell and also contribute to the immune system.

The cell itself contains the cytoplasm, which consists of the nucleus, organelles and the cytosol, which contains various different salts in solution and helps to maintain a suitable environment for different metabolic processes. There is also extra cellular fluid bathing the outside of the cell. If the fluid composition within the cell changes outside of quite narrow parameters the cell will be unable to function and will therefore die. The human body is 90% water. When we realise this we see how important it is to maintain sufficient levels of fluids and minerals in the diet.

The following chart summarises the structures of the cell and their functions.

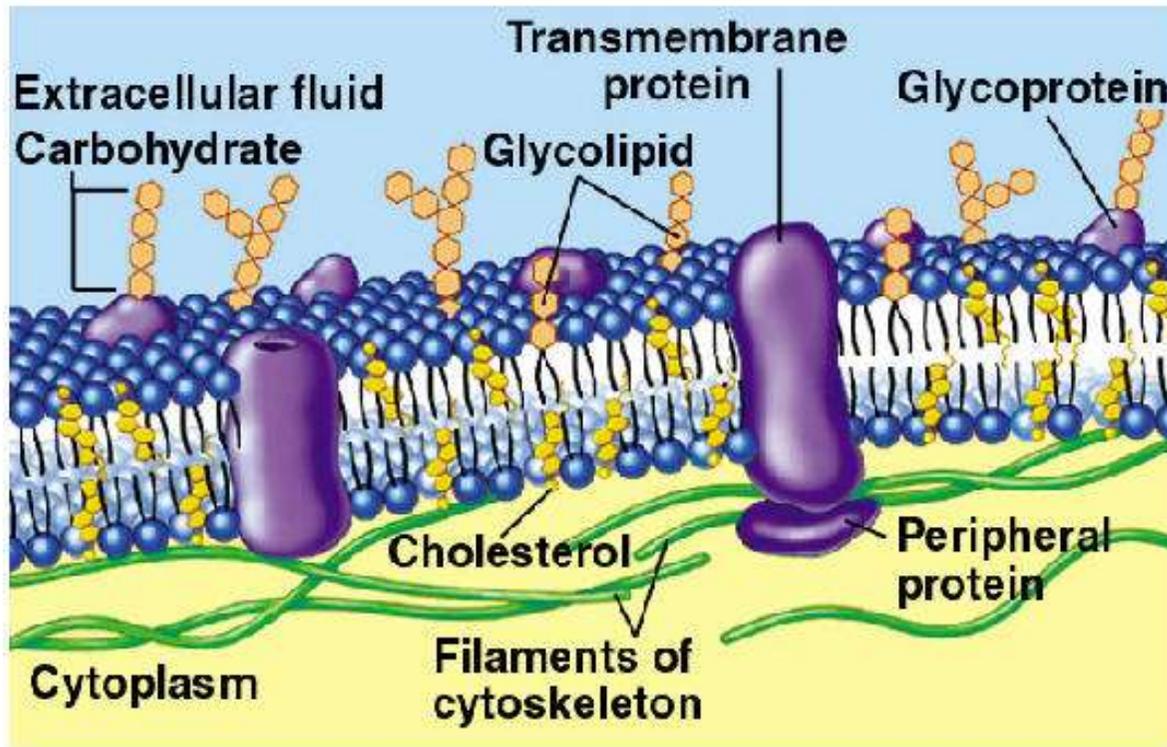
Part	Structure	Functions
Plasma Membrane	Composed of a lipid bilayer consisting of phospholipids, cholesterol, and glycolipids with various proteins inserted; surrounds cytoplasm.	Protects cellular contents; makes contact with other cells; contains channels, transporters, receptors, enzymes, and cell-identity markers; mediates the entry and exit of substances.
Cytoplasm	Cellular contents between plasma membrane and nucleus, including cytosol and organelles.	Site of all intracellular activities except those occurring in the nucleus.
Cytosol	Composed of water, solutes, suspended particles, lipid droplets, and glycogen granules.	Medium in which many of the cell's chemical reactions occur.
Organelles	Specialized cellular structures with characteristic shapes and specific functions.	Each organelle has one or more specific functions.
Cytoskeleton	Network composed of three protein filaments: microfilaments, intermediate filaments, and microtubules.	Maintains shape and general organization of cellular contents; responsible for cell movements.
Centrosome	Paired centrioles plus pericentriolar material.	Pericentriolar material is organizing center for microtubules and mitotic spindle.
Cilia and flagella	Motile cell surface projections with inner core of microtubules.	Cilia move fluids over a cell's surface; a flagellum moves an entire cell.
Ribosome	Composed of two subunits containing ribosomal RNA and proteins; may be free in cytosol or attached to rough ER.	Protein synthesis.
Endoplasmic reticulum (ER)	Membranous network of folded membranes. Rough ER is studded with ribosomes and is attached to nuclear membrane; smooth ER lacks ribosomes.	Rough ER is site of synthesis of glycoproteins and phospholipids; smooth ER is site of fatty acid and steroid synthesis. Smooth ER also releases glucose into bloodstream, inactivates or detoxifies drugs and potentially harmful substances, and stores calcium ions for muscle contraction.
Golgi complex	A stack of 3–20 flattened membranous sacs called cisterns.	Accepts proteins from rough ER; forms glycoproteins and lipoproteins; stores, packages, and exports proteins.
Lysosome	Vesicle formed from Golgi complex; contains digestive enzymes.	Fuses with and digests contents of vesicles; digests worn-out organelles (autophagy), entire cells (autolysis), and extracellular materials.
Peroxisome	Vesicle containing oxidative enzymes.	Detoxifies harmful substances.
Proteasome	Tiny structure that contains protease, enzymes that cut proteins.	Degrades unneeded, damaged, or faulty proteins by cutting them into small peptides.
Mitochondrion	Consists of outer and inner membranes, cristae, and matrix.	Site of reactions that produce most of a cell's ATP.
Nucleus	Consists of nuclear envelope with pores, nucleol, and chromatin (or chromosomes).	Contains genes, which control cellular structure and direct most cellular activities.



Cell membrane

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Fluid Mosaic Model



Cytoskeleton

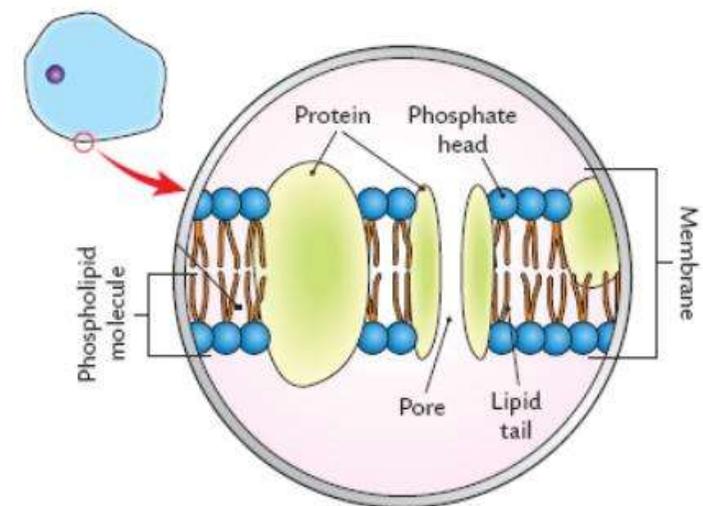
The cytoskeleton has the function to organize and maintain the cell's shape; anchors organelles in place. It also helps during endocytosis (the uptake of external materials by a cell) and cytokinesis (the separation of daughter cells after cell division) and moves parts of the cell in processes of growth and mobility. The eukaryotic cytoskeleton is composed of microfilaments, intermediate filaments and microtubules. There are a great number of proteins associated with them, each controlling a cell's structure by directing, bundling, and aligning filaments. The prokaryotic cytoskeleton is less well-studied but is involved in the maintenance of cell shape, polarity and cytokinesis.

Figure 2 - Cell membrane; fluid mosaic model

The cell membrane consists of a bilayer of phospholipid molecules. These arrange themselves such that the hydrophobic lipid tails point inwards and all the hydrophilic phosphate groups point outwards towards the water-based environment on each side.

Within this membrane are also transmembrane proteins, glycoproteins, ion channels. The cell membrane is selectively permeable to ions and organic molecules and controls the movement of substances in and out of cells.

Figure 3 - Phospholipid Bilayer



Cell Nucleus

The cell nucleus is the most conspicuous organelle found in a cell. It houses cell's chromosomes, and is the place where almost all DNA replication and RNA synthesis (transcription) occur. The nucleus is spherical and separated from the cytoplasm by a double membrane called the nuclear envelope. The nuclear envelope isolates and protects a cell's DNA from various molecules that could accidentally damage its structure or interfere with its processing. During processing, DNA is transcribed, or copied into a special RNA, called messenger RNA (mRNA). This mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule. The nucleolus is a specialized region within the nucleus where ribosome subunits are assembled. In prokaryotes, DNA processing takes place in the cytoplasm.

The nucleus contains the chromatids which are two identical copies of DNA set from the mother, one from the father) making up a duplicated chromosome, which are joined at their centromeres, for the process of cell division (mitosis or meiosis). They are called sister chromatids as long as they are joined by the centromeres. When they separate (during anaphase of mitosis and anaphase 2 of meiosis), the strands are called daughter chromosomes.

In other words, a chromatid is "one-half of a replicated chromosome". It should not be confused with the ploidy of an organism, which is the number of homologous versions of a chromosome. Centrosomes are paired structures on the nucleus. They involved in the formation of the mitotic spindle in cell division.

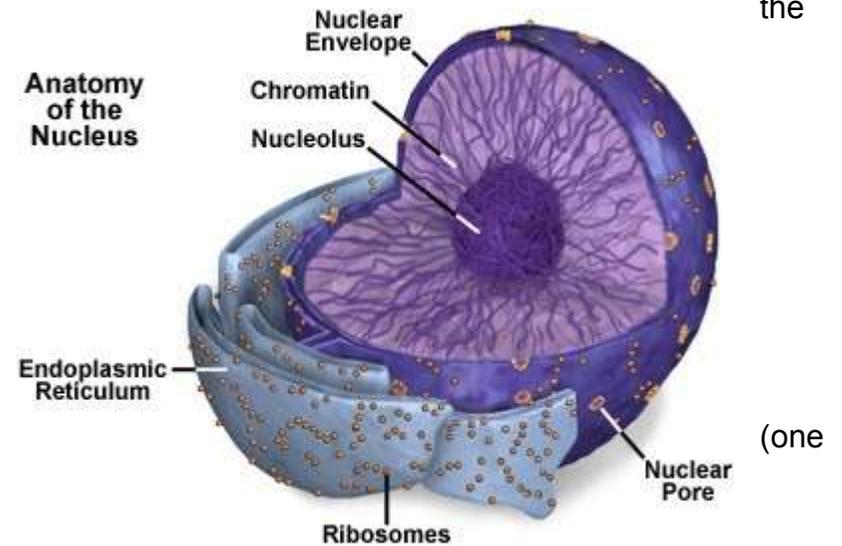
Mitochondria - the power generators

Mitochondria are self-replicating organelles that occur in various numbers, shapes and sizes in the cytoplasm of all animals cells. They play the primary function of generating energy through the process of *oxidative phosphorylation*, using oxygen to release energy stored in the nutrients we eat and converting this into the energy currency of the cell – **ATP** (Adenosine Triphosphate) in a process called cellular respiration (see your videos supplied on your disc).

Endoplasmic reticulum

This occurs in two types; rough and smooth, each having its own functions.

Figure 4 - Cell Nucleus



Rough endoplasmic reticulum is so called because it looks 'lumpy' under the microscope; the lumps consist of structures called ribosomes. The ribosome is a large complex of RNA and protein molecules. They each consist of two subunits, and act as an assembly line where RNA from the nucleus is used to synthesise protein from amino acids. Ribosomes can be found either floating freely or bound to a membrane. Each cell makes proteins unique to its own function (see your disc)

Smooth endoplasmic reticulum (SER) has functions in several metabolic processes, including synthesis of lipids and steroids, metabolism of carbohydrates, regulation of calcium concentration, drug detoxification, attachment of receptors on cell membrane proteins, and steroid metabolism. It is connected to the nuclear envelope. It also releases glucose into the bloodstream, in activates and detoxifies drugs and potentially harmful substances.

Golgi complex is a layered structure consisting of a stack of between 3 – 20 flattened membranous sacs (called cisterns). It is here where the proteins are packages up for 'export' and usage. It also forms glycoproteins and lipoproteins.

Lysosomes are structured and formed by the Golgi complex and contain digestive enzymes. Their functions are to digest old and worn out organelles and entire cells.

Peroxisomes are vesicles containing oxidative enzymes and peroxides that are used for detoxifying harmful substances.

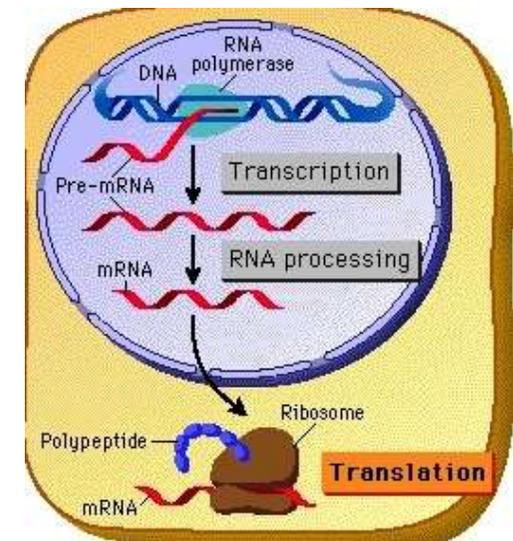
Protein Synthesis is a process whereby DNA encodes for the production of amino acids and proteins.

Figure 5- Schematic of gene transcription and translation

Transcription occurs before the synthesis of a protein begins; the corresponding RNA molecule is produced by RNA transcription. One strand of the DNA double helix is used as a template by the RNA polymerase to synthesize a messenger RNA (mRNA). This mRNA migrates from the nucleus to the cytoplasm. During this step, mRNA goes through different types of maturation including one called splicing when the non-coding sequences are eliminated. The coding mRNA (messenger RNA) sequence can be described as a set of three nucleotides called a codon. Each three nucleotide codon corresponds with one amino acid in the sequence that will ultimately make up the protein

Translation

The ribosome binds to the mRNA (transfer RNA) at the start codon (AUG) that is recognized only by the initiator tRNA. The ribosome proceeds to the elongation phase of protein synthesis. During this phase amino acids in the cytosol are recruited and joined to the chain as each respective codon is read. The ribosome moves from codon to codon along the mRNA. Amino acids are added one by one, translated into polypeptidic sequences dictated by DNA and represented by mRNA. At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome (see your disc)



Protein structure

Figure 6 - formation of protein structure

The end result of this synthetic process is the **primary structure**; a simple amino acid chain, but it is not yet a protein. To function as a protein, it has to take on a three dimensional structure, such that it can fulfil its function as a protein. It does this in a number of ways:

Secondary structure

- **α -helix** – this is a coil-shaped structure
- **β -pleated sheet** – this is zig-zag structure (held together by hydrogen bonds).

Tertiary structure

This forms when bonds form between adjacent side-chains (by disulphide bonds). This results in a three-dimensional structure. Sometimes this is the end result.

Quaternary structure

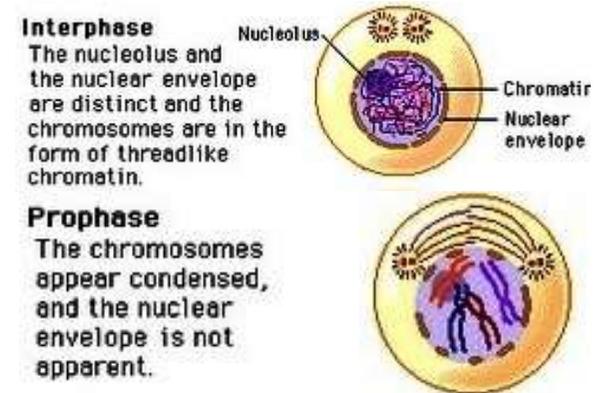
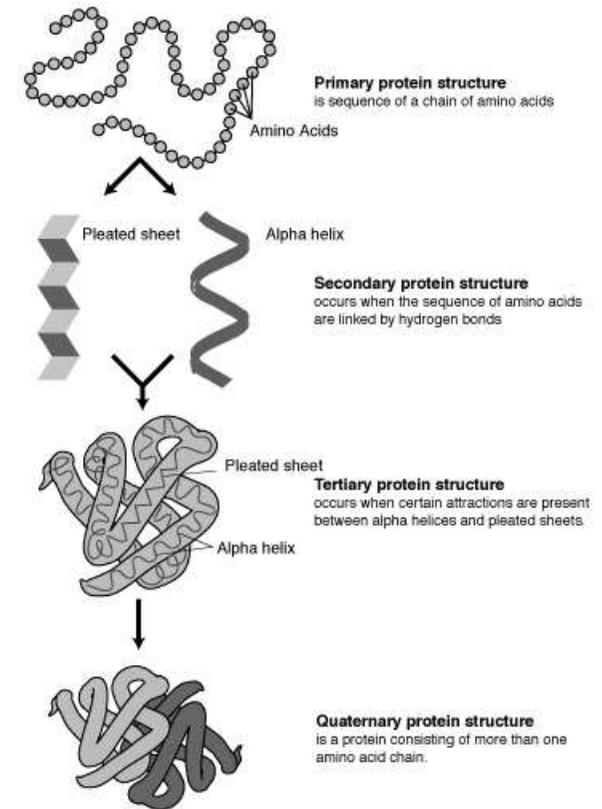
This forms when other peptide units come together forming a more complex structure.

Cell replication (Mitosis)

When a cell divides it goes through several cycles, including duplication of all DNA material, division of that nuclear material followed by cell division itself.

It takes place in four phases:

Prophase – this begins once all the nuclear material has been replicated and chromatin has condensed. The amount of nuclear material is now double. The two round objects above the nucleus are the centrosomes. They separate and microtubules have invaded the nuclear space. These microtubules can attach to kinetochores or they can interact with opposing microtubules. The nuclear membrane has degraded,



Metaphase - The chromosomes align themselves at the metaphase plate; the equator of the mitotic spindles

Anaphase - The kinetochore microtubules shorten. The daughter chromatids separate and pull the separate sets of chromatin material towards the centrosomes

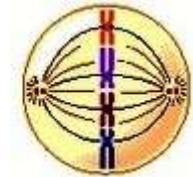
Telophase - the two groups of chromatids have now been completely separated. The decondensing chromosomes are surrounded by newly formed nuclear membranes.

Cytokinesis has already begun; the pinched area is known as the cleavage furrow.

Figure 7 - Stages of Mitosis

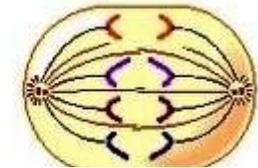
Metaphase

Thick, coiled chromosomes, each with two chromatids, are lined up on the metaphase plate.



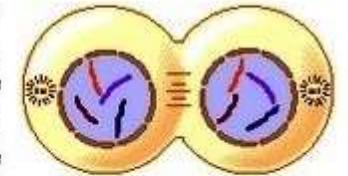
Anaphase

The chromatids of each chromosome have separated and are moving toward the poles.



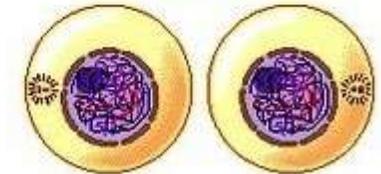
Telophase

The chromosomes are at the poles, and are becoming more diffuse. The nuclear envelope is reforming. The cytoplasm may be dividing.



Cytokinesis

Division into two daughter cells is completed.



Meiosis

This takes place only in testes and ovaries. It is a process when the number of chromosomes is halved and packaged up into gametes: eggs and sperm. The normal number of chromosomes is described as diploid; a double number. At the end of meiosis this number will be halved; haploid. Thus when fertilisation takes place, two haploid numbers comes together and form a diploid number. It is also when there is a mixing up of nuclear material; of the genes, such that the children from such gametes will like the parents but not be identical.

Meiosis occurs in two main phases: **meiosis I** and **meiosis II**

Meiosis I:

Prophase I

DNA replication precedes the start of meiosis I. During prophase I, homologous chromosomes pair and form synapses (joined together at the centromere), a step unique to meiosis. The paired chromosomes are called bivalents, and the formation of chiasmata caused by genetic recombination becomes apparent.

This is when there is a **crossing over**, a swapping, of genetic material. Now the male and female genes are mixed up, causing the offspring to possess qualities of both parents.

Chromosomal condensation allows these to be viewed in the microscope. Note that the bivalent has two

Interphase



MEIOSIS I

Prophase I

Synapsis and crossing over occur.



chromosomes and four chromatids, with one chromosome coming from each (original) parent. The nuclear membrane disappears. One kinetochore forms per chromosome rather than one per chromatid, and the chromosomes attached to spindle fibres begin to move.

Metaphase I

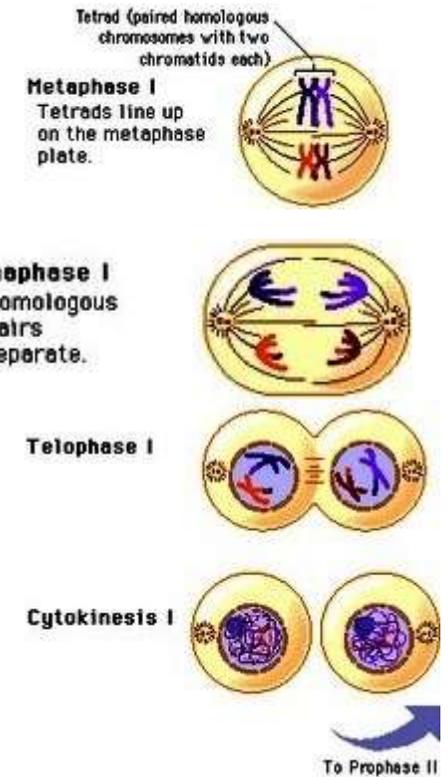
Bivalents, each composed of two chromosomes (four chromatids) align at the metaphase plate. The orientation is random, with either parental homologue on a side. This means that there is a 50-50 chance for the daughter cells to get either the mother's or father's homologue for each chromosome.

Anaphase I

Chiasmata separate. Chromosomes, each with two chromatids, move to separate poles. Each of the daughter cells is now haploid (23 chromosomes), but each chromosome has two chromatids. The cell still has to go through a process to reduce this number by half.

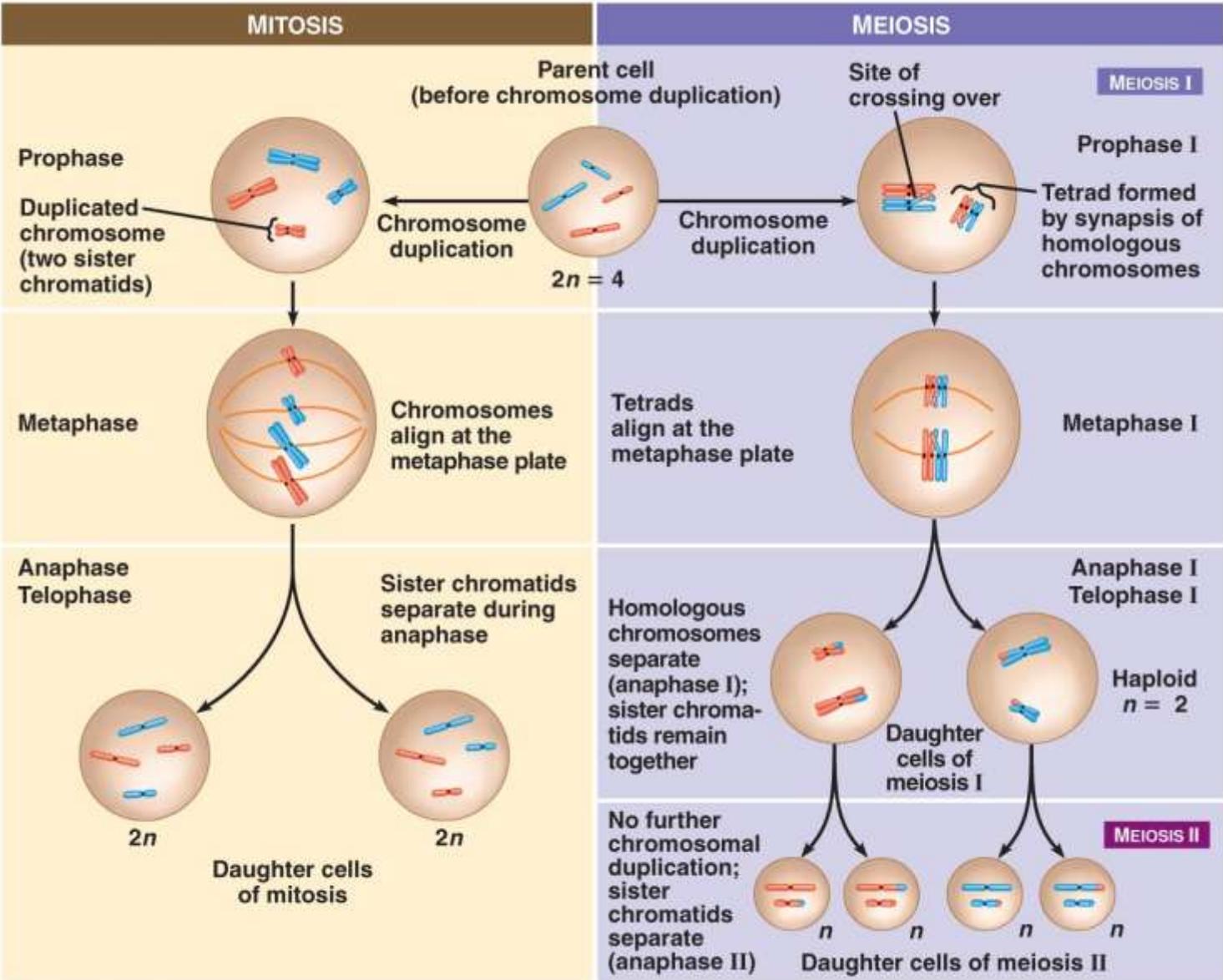
Telophase I

Nuclear envelopes may reform, or the cell may quickly start meiosis II.



Meiosis II is similar to mitosis. However, there is no preliminary phase of duplication. The chromatids of each chromosome are no longer identical because of recombination. Meiosis II separates the chromatids producing two daughter cells each with 23 chromosomes (haploid), and each chromosome has only one chromatid.

Summary comparing meiosis with mitosis:



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Figure 8 - Stages of Meiosis