Mitosis

Chromosomes, and the processes they undergo during mitosis, were recognized long before the molecular biology you have already studied was understood.

Mitosis is an integral part of cell replication (cell division) and it was obvious that mitosis was the process by which the replication of genetic material occurred.

Analysis of the structures involved in mitosis showed two predominant chemicals: the nucleic acid DNA and the protein histone. (*NB This is in eukaryotic cells, prokaryotic cells have no histone*). At the time the importance of proteins was understood and it was assumed that histone was the genetic material.

This belief was disproved by the work of Watson and Crick (and others) who showed that, as you have seen, DNA is replicable and can be used as a template for protein synthesis.

In this section you will study the physical process of mitosis as seen using a light microscope. Try to understand it in terms of the molecular biology you have studied previously.

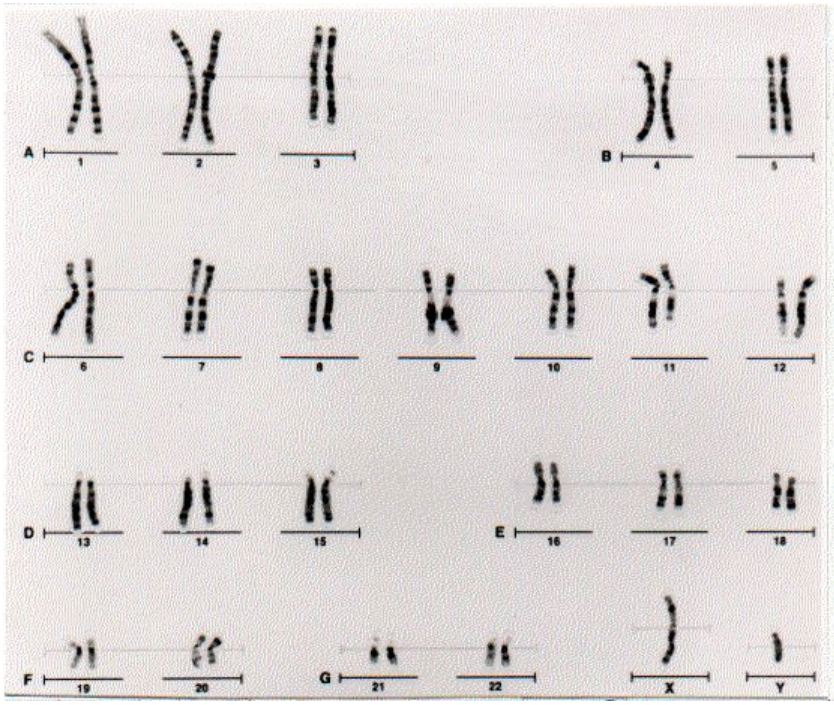
The DNA found in cell nuclei is not found as a single molecule it is divided up into molecules called **chromosomes**
All of the DNA in a cell is known as the **genome**.

Each species has a characteristic number of chromosomes. In humans this is 46 (*there is no corollary between the number of chromosomes and the complexity of the organism*)

The 46 chromosomes exist as 23 pairs

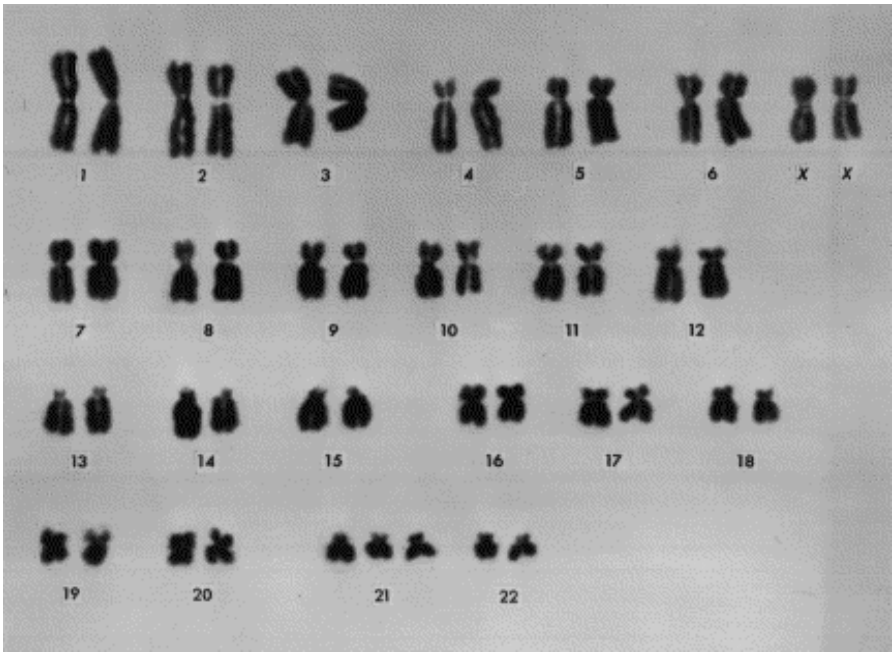
- For 22 of the pairs the two chromosomes appear identical to each other under a microscope. These are the somatic chromosomes.
- the 23rd pair, the sex chromosomes, appear identical in females but different in males. The sex chromosomes are called X and Y. Females are XX, males are XY
- One of each pair has passed from the father, the other has been passed from the mother

In this diagram the chromosomes in a cell have been prepared so they are visible then photographed. The photograph is then cut up and the chromosomes arranged in their pairs. A diagram of this type, which shows the number of chromosomes in a diploid cell and their sizes, is known as a karyotype.



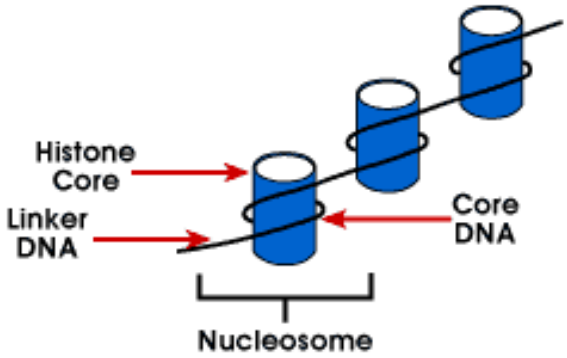
This is the karyotype of a normal human male

The diagram below shows the karyotype of a human female with Down's syndrome (trisomy 21)



- Cells which have paired chromosomes are said to be diploid. The diploid number is referred to as 2*n* (i.e. in humans 2*n* = 46)
- Cells which only have one of each pair are called haploid. The haploid number is *n*. (In humans *n* = 23).
- Cells which are haploid are sex cells (e.g. sperm and egg) and fuse together to form a zygote (which is diploid) and it is from the zygote that all other cells develop. Hence all cells (except the sex cells) are diploid.
- The process by which haploid sex cells develop from diploid cells is called meiosis. It is similar to mitosis and is studied in Unit 2

The physical structure of chromosomes



The DNA molecule in a chromosome is associated with several proteins

- histone: a globular protein around which the DNA wraps(like thread round a bobbin)
- scaffold protein: the function of which is not understood but presumably acts as a support and stabiliser
- polymerases: which catalyse the replication of DNA and the production of RNA. (You have already studied these)

- A length of DNA wraps around a small group of histone proteins. This structure is known as a **nucleosome**. The formation of nucleosomes makes the DNA more stable reducing damage.

- The structure formed by the association of the whole molecule of DNA with histone is known as **chromatin** because it takes up stain and can thus be readily seen using a microscope.

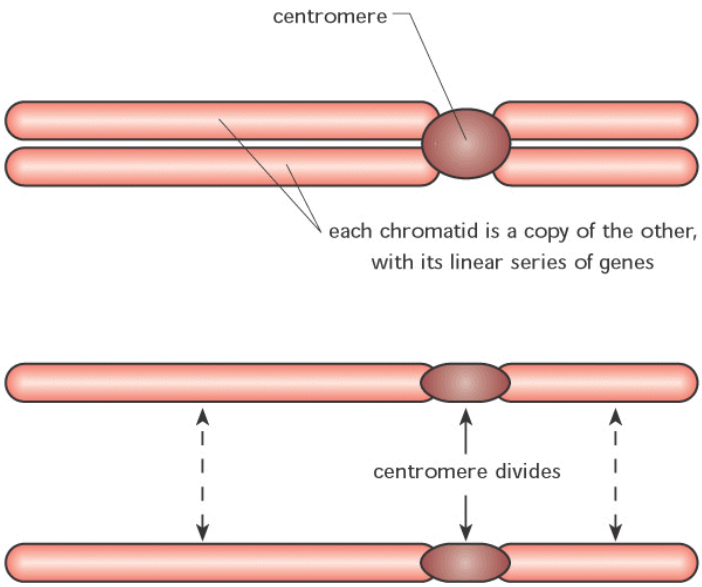
- In preparation for mitosis DNA replication takes place to produce 2 identical double stranded DNA molecules which remain joined together.

- At the beginning of mitosis the chromosomes become very tightly coiled,

reducing their volume, and become visible. This is known as condensation. At this stage they appear to be a single long structure.

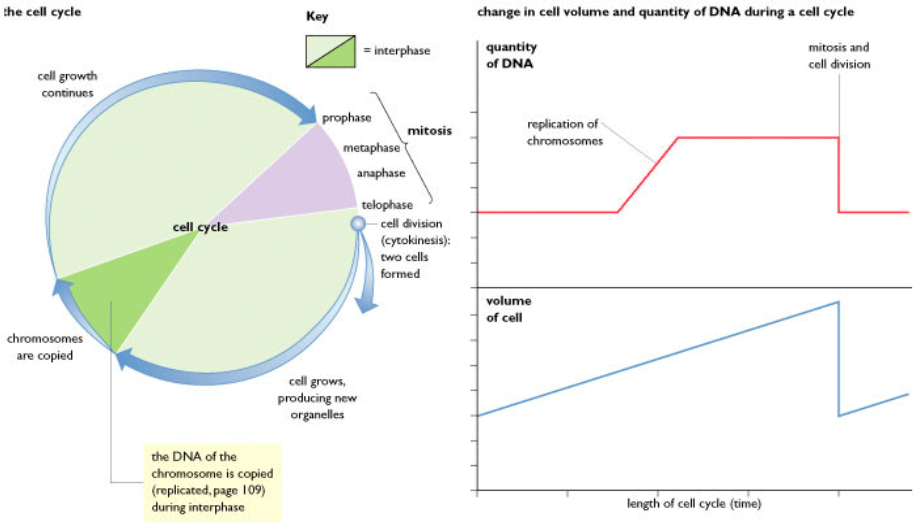
- During the early stages of mitosis the chromosomes become even more condensed and the two identical molecules become apparent as parallel **sister chromatids** joined in the middle at region known as the **centromere**.

- This separation of the 2 DNA molecules into chromatids enables them to be physically separated during mitosis.



The Cell Cycle

The various processes a cell undergoes from its formation to the time at which it divides to produce daughter cells are known the cell cycle

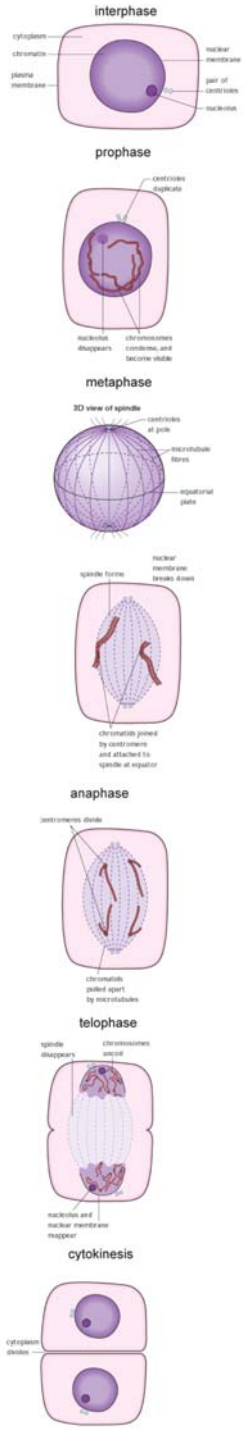


Most of the cell cycle comprises **interphase** during which the cell is performing its normal functions and is preparing itself for replication

The remainder of the cell cycle is the processes of mitosis and cytokinesis.

Mitosis produces 2 identical nuclei

Finally daughter cells are produced by **cytokinesis** - the division of the cell's cytoplasm into 2 new cells each containing one of the new nuclei



Interphase Under light microscopy the nucleus appears as a homogeneous mass which takes up stain

Prophase The chromosomes condense and become visible as long thin strands

Metaphase The chromosomes condense further and appear as a pair of chromatids. The spindle (made from microtubules and arising from the centrioles) forms. The chromosomes become attached via their centromeres to the equator of the spindle

Anaphase The paired chromatids are pulled apart by dynamic changes in the spindle. At this stage the chromatids are again referred to as chromosomes

Telophase The chromosomes are located at opposite ends of the cell. The spindle disappears. New nuclei are formed

Cytokinesis A new cell membrane develops dividing the cell into two

You must be able to identify cells in each of these stages and know the specific events occurring in each of prophase, metaphase, anaphase, telophase

Mitosis produces two new daughter cells each identical to the parent cell i.e. with the same number and type of chromosomes as the mother cell.

Mitosis is the basis of growth since it allows for an increase in cell number with the new cells being genetically identical to the mother.

Cells lost to damage are replaced by mitosis

Typically a cell undergoes differentiation (specialization) after production by mitosis. This means that highly specialized cells such as the leaf palisade cell and the liver cell are manufactured as generic cells and then changed to their specific type by switching on and off of particular genes

Mitosis is also the basis for asexual reproduction in some organisms e.g. yeast. where a single cell gives rise to a large number of cells all identical to the original. This is called cloning.

Reproduction of an organism by production of clones allows for rapid production of a large number of individuals however, because these individuals are all identical, they are all susceptible to the same environmental pressures. So, if the original organism is not well adapted to the particular environment (e.g. it is unable to use the substrate available in that environment) then nor will be any of its offspring.
For this reason sexual reproduction developed where characteristics of two individuals are shared in the offspring. Sexual reproduction uses meiosis.

Artificial cloning

As described natural cloning occurs in yeast and some other relatively simple organisms but the process of cloning can be carried out artificially to produce large numbers of identical cells and, indeed, has been performed by plant growers (by taking cuttings) since long before the process of mitosis was understood.

Typically artificial cloning is performed by removing cells from an actively growing region of the parent individual (such as the apical meristem of a plant) and cultured in conditions which provide the necessary nutrients and growth substances (such as hormones)

In animals the easiest procedure involves taking **undifferentiated** cells and forcing them to fuse with an egg which has had its nucleus removed. The egg then develops normally. Repeating this procedure many times results in a large number of eggs all genetically identical to the animal from which he undifferentiated cells were taken. This procedure is common in cows.

A similar procedure was used to produce Dolly the sheep but she is famous because the nucleated cell used was already **differentiated**. It was in fact a cell from the mammary gland. In spite of already being differentiated the nucleus was able to give rise to all other cells types in the animal produced

Human Genome Project

Now that you have studied the structure and role of DNA you are in a position to understand the Human Genome Project. Using the information provided and your own research write a 10 mark essay discussing the spiritual, moral, ethical, social and cultural issues surrounding the project.