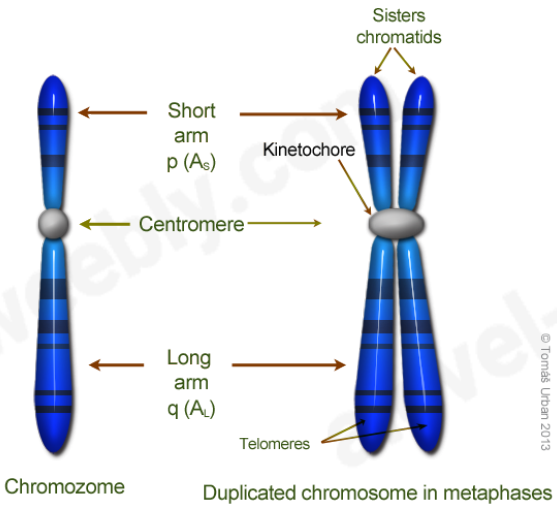
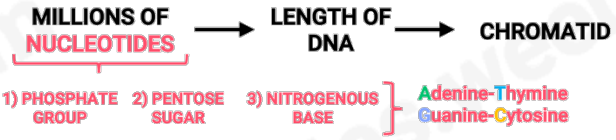
5 The mitotic cell cycle

Structure of a chromosome

Chromosomes are thread-like structures made of DNA.



- **Chromatid** – one half of two identical copies of a replicated chromosomes



- **Centromere** – the region of a chromosome to which the microtubules of the spindle attach, via the kinetochore, during cell division.
- **Telomeres** – protective sequence of nucleotides found at the ends of chromosomes

DNA (deoxyribonucleic acid)

DNA is the molecule of inheritance and is made up of a series of genes.

- a gene is a section of DNA that codes for one protein
- DNA molecules are in sister chromatids so that their genes are identical
- when cells divide, one chromatid goes into one daughter cell and the other to the other daughter cell, making the daughter cells genetically identical
- size of DNA molecule – 2nm

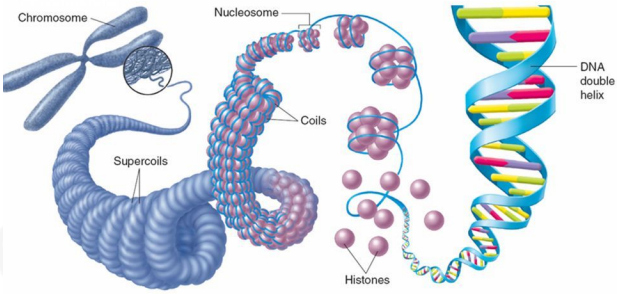
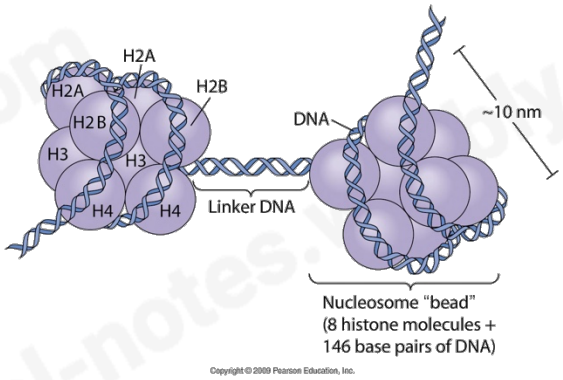


Image: https://mrleehamber119.wordpress.com/

- the total length of DNA of 46 chromosomes of an adult human is about 1.8m, this needs to be fit into a nucleus of 6µm
- therefore, the DNA is wound around the outside of proteins called **histones**
  - **histone proteins** – basic proteins which associate with DNA to form nucleosomes
- these histone proteins (and therefore, nucleosomes) condense DNA to **chromatin**
  - **chromatin** – a complex of nucleic acids (DNA and RNA) and other proteins whose primary function is to compress DNA into a compact unit which will fit inside the nucleus

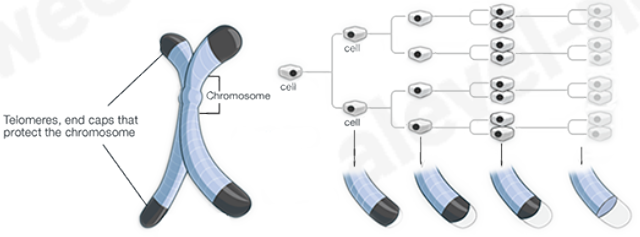
Nucleosomes



- 11 nm wide by 6 nm long
- made of 8 histone molecules

Telomeres

- cap the ends of chromosomes and are needed for successful cell division
- permit continued replication
- prevent the loss of genes



As cells divide over time...telomeres shorten, and eventually cell division stops.

Image: https://www.tasciences.com/what-is-a-telomere.html

- telomeres are made of DNA with short base sequences that are repeated multiple times
- the copying enzyme, telomerase, stops a little short of the end of DNA
- more bases are added, which don't have useful information, but allows telomerase to complete copying the meaningful DNA

The cell cycle

Processes of growth, development, and reproduction.

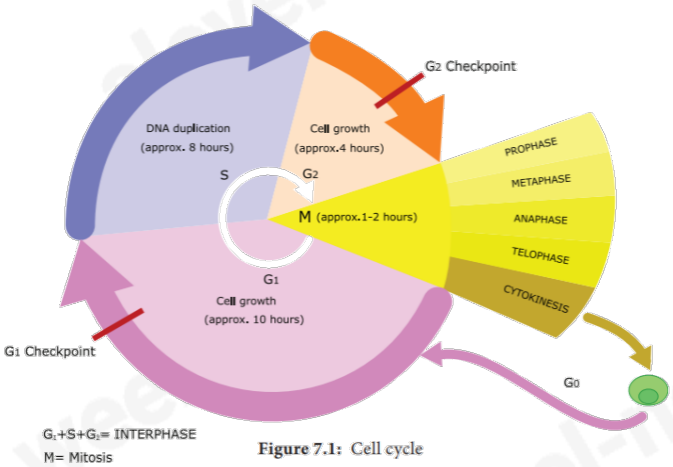


Figure 7.1: Cell cycle

Image: https://www.brainkart.com/article/Cell-Cycle_33013/

Interphase (G_1 + S + G_2)

- Longest phase
- Normal cell work/functions
- The cell grows to its normal size
- Time spent between cell divisions

1) G_1 phase

- cells make RNA, enzymes and other proteins needed for growth
- at the end of G_1 phase, the cell becomes committed to dividing or not

2) S phase

- synthesis of DNA
- the DNA in the nucleus replicates so that each chromosome consists of 2 identical chromatids: DNA replication

3) G_2 phase

- the cell continues to grow
- new DNA is checked, and any errors are repaired
- preparations are made to start cell division e.g., a sharp increase in production of the protein tubulin is observed which is needed to make microtubules for mitotic spindle

M phase (mitosis)

Nuclear division that produces 2 genetically identical daughter cells.

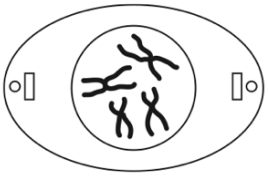
- Maintains genetic stability
- Ensures cells retain function
- Maintains chromosome number

Functions of mitosis

- growth
- cell replacement
- repair of tissues
- asexual reproduction
- immune response (cloning B and T-lymphocytes)

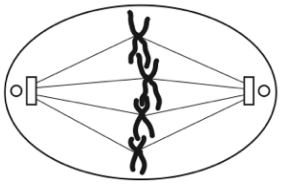
The stages of mitosis

1) Prophase



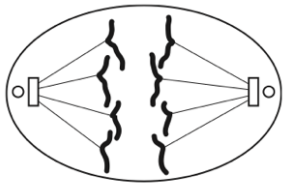
- centrosomes migrate to opposite poles of mitotic spindle
- chromatin starts to condense
- nuclear envelope and nucleolus begin to disappear
- centrosomes and migrate to opposite poles of the cell and form poles of mitotic spindle
- asters and spindle fibres form

2) Metaphase



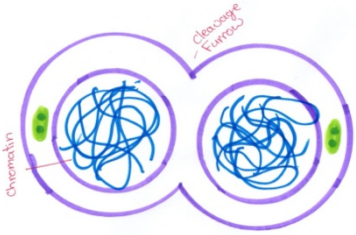
- centrosomes are at poles of the cell and organise the production of spindle microtubules
- chromosomes line up across equator of the spindle
- each chromosome splits at centromere
- chromosomes start to be pulled apart by microtubules

3) Anaphase



- chromatids move to opposite poles, centromeres are first pulled by microtubules
- spindle fibres contract and chromosomes are pulled to the opposite ends

4) Telophase



- nuclear envelope and nucleolus reforming
- nucleus divides
- chromosomes are at poles of cell

Image: https://www.tekportal.net/telophase/

Cytokinesis

The division of cytoplasm.

Cytokinesis in plant cells

- cell plate forms across equator of cell; cellulose, cell wall laid down
- cytoplasm is hence divided into 2

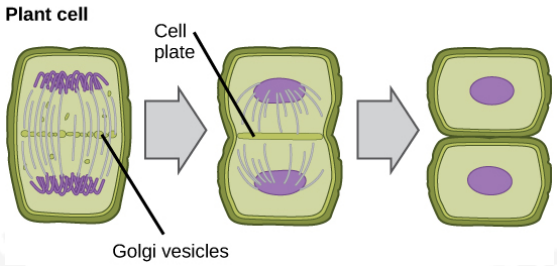


Image: https://courses.lumenlearning.com/

Cytokinesis in animal cells

- contractile ring forms, pushing the equator of cell inwards, forming a cleavage furrow
- this cleavage furrow deepens as active filaments in the ring contract
- eventually the cell splits into 2

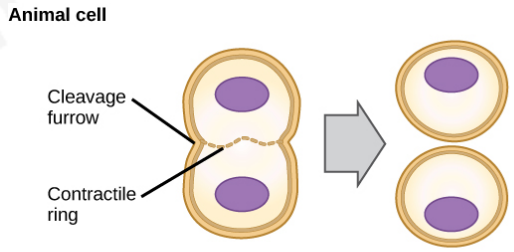


Image: https://courses.lumenlearning.com/

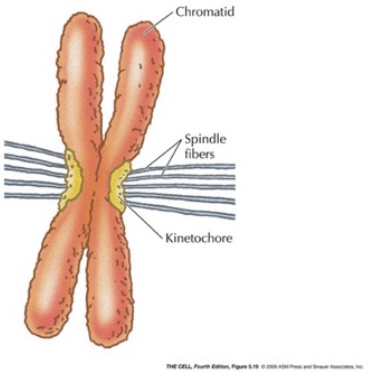
Differences in plant and animal cell mitosis

- plant cells don't have any visible centriole or aster
- in plant cells, daughter cells get separated by cell plate, there is no cleave furrow formation

Centromeres, centrosome, centrioles

1) Centromere

- needed for separation of chromatids during mitosis
- site of attachment of spindle microtubules
- each metaphase chromosome has 2 kinetochores at its centromere and microtubules
  - **kinetochore** – protein molecules which bind to DNA in centromere and microtubules
  - bundles of microtubules called spindle fibres extend from kinetochores to poles of spindle during mitosis



2) Centrosome

- an organelle found in animal cells that acts as the microtubule organising centre (MTOC) for construction of the spindle
- present at the poles of cell

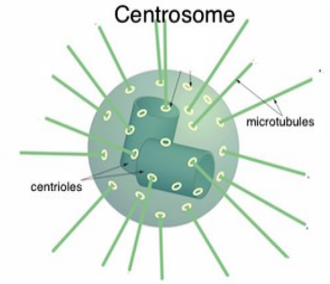


Image: https://www.qsstudy.com/biology/centrosome-definition-function

3) Centrioles

- act as MTOCs
- assemble/form spindle fibres during prophase
- contraction of spindle fibres during anaphase separates sister chromatids

Stem cells

Stem cells are cells that can divide an unlimited number of times by mitosis.

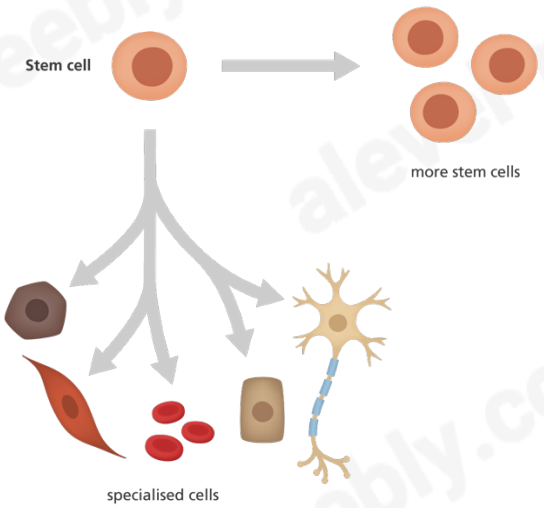


Image: https://www.yourgenome.org/facts/what-is-a-stem-cell

- extent of the power of a stem cell to produce different cell types is called its **potency**
- **stem cell therapy** – introduction of new adult stem cells into damaged tissue to treat a disease or injury

Cancer

- a result of uncontrolled mitosis; cancerous cells divide repeatedly and form a tumour
- **carcinogen** – agent that causes cancer e.g., radiations (UV, X-rays), tar, nuclear fallout

Cellular changes that occur in development of cancer

- mutation occurs in gene responsible for cell division leading to formation of an oncogene from a proto-oncogene
- this causes uncontrolled cell division
- coordination of cell cycle is lost (cell does not receive/respond to signals that tell it to stop dividing)
- loss of function and lack of specialisation occurs
- a tumour is formed, an irregular mass of cells showing an abnormal change in shape