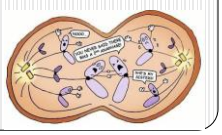
Chromosomes
Mitosis and Meiosis

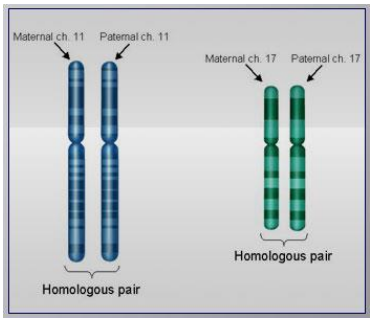
Class 2
SLE254 Genetics and Genomics
Chapter 2 Concepts of Genetics (12th Ed)
Pages 50-71 Ch2



Terminology

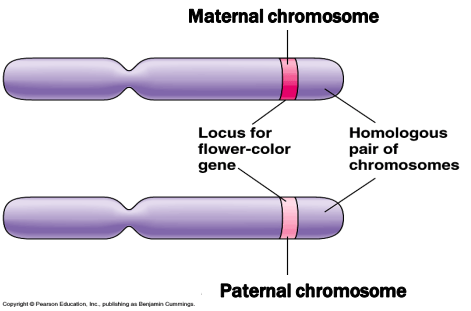
- *Locus* –
- *Allele* –
- *Genotype* –
- *Phenotype* –

Homologous Chromosomes

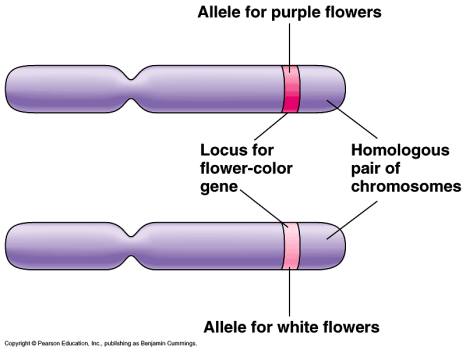


During meiosis homologs pair together

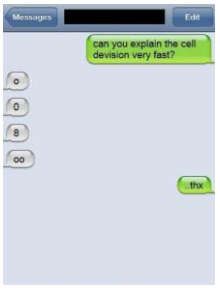
Locus – position of allele on a chromosome

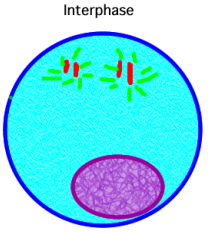


Allele – alternative DNA sequence at the same locus



Cell division and the cell cycle





http://www2.amersol.edu.pe/class11/_11pcsglt/7th/science/images/cells.gif
http://24.media.tumblr.com/tumblr_m9l8b7gMNk1qibv8fo1_400.jpg

The cell cycle

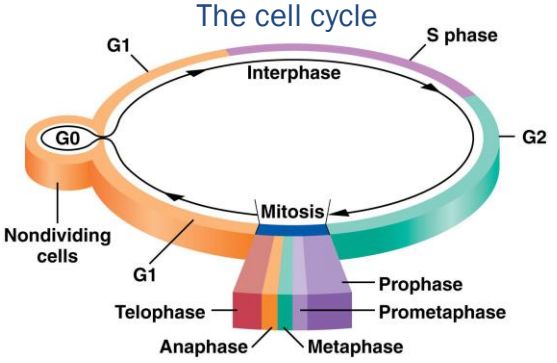


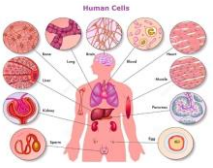
Figure 2-5

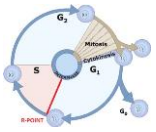
Cell cycle 1. **Interphase**

- **Cell cycle**
  - Composed of **interphase** and **mitosis**
- **Interphase** includes
  - S phase: DNA is synthesized
  - Two gap phases (G1 and G2) (**Figure 2-5**)
- G0: Point in G1 phase where cells are nondividing, but a metabolically active state

Interphase

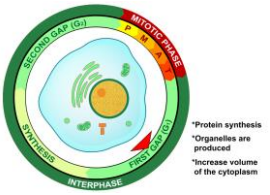
- **Interphase:** the period of **growth** between cell division
- Up to 90% of a cell's time in the normal cellular cycle may be spent in interphase
- The cell may appear to be dormant, however, biochemical activity is high during interphase





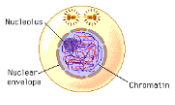
Stages of Interphase: Gap 1

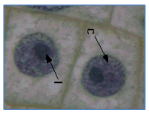
- **G_1 phase** – The period **prior to the synthesis of DNA**
  G= Gap 1= first Gap
- For many cells, this phase is the major period of cell growth during its lifespan



Chromosomes in Interphase

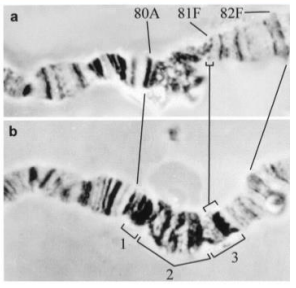
- The DNA in a G_1 diploid eukaryotic cell is **2n**, meaning there are **two sets of chromosomes** present in the cell
- The genetic material exists in loose form **chromatin**
  - The structure of chromatin during interphase is optimised to allow easy access of transcription and DNA repair factors to the DNA
    - Not tightly coiled





Interphase Chromatin

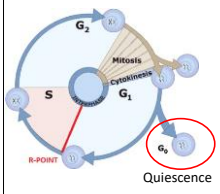
- Different levels of packing on various regions of the same chromosome
- Euchromatin: loosely packed region on chromatin, active transcription
- Heterochromatin: densely packed region on chromatin, inactivated



Eu = true; Hetero = different

Stages of Interphase: G_0 phase

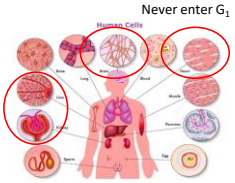
- A cell may **pause** in the G_1 phase before entering the S phase and enter a state of dormancy called the G_0 phase



Quiescence

Never enter G_1

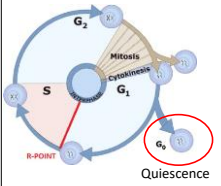
Semi permanent



Always performing their job- be nice to these organs!!

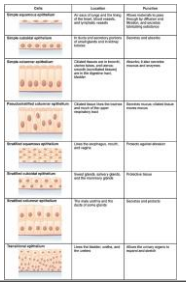
Stages of Interphase: G_0 phase

- Epithelial cells divide throughout life- rarely enter G_0



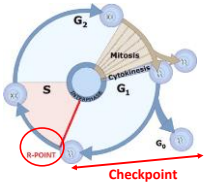
Quiescence

Epithelia line tissues, organs: skin



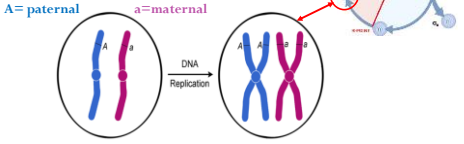
Stages of Interphase: restriction (R) point

- The restriction (R) point is present at the end of G_1 phase
- Depending on levels of nutrients, energy and external factors, cells must decide to enter the cell cycle or move into G_0 phase



Stages of Interphase: S phase

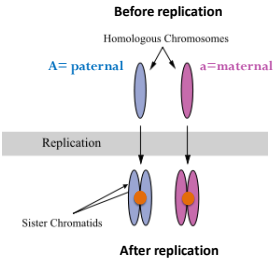
- S phase – The period during which DNA is synthesised **(replicated)**
  - The **S** represents **synthesis**
- Create exactly two identical semi-conserved chromosomes
- Detect and fix DNA damage



Doubling of DNA but the cell is still **2n**, meaning there are still two sets of chromosomes

Structure of the chromosome

- **Chromatid**
  - One strand of a duplicated chromosome
  - Joined by a centromere to its sister chromatid
- **Sister chromatids**
  - Two chromatids joined by a common centromere
  - Each carries identical genetic information



Structure of the chromosome

- **Centromere**
  - Heterochromatic region of a chromosome to which microtubule fibres attach during cell division
  - Centromere location gives a chromosome its characteristic shape

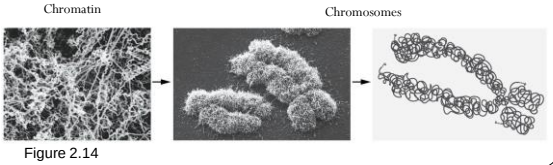
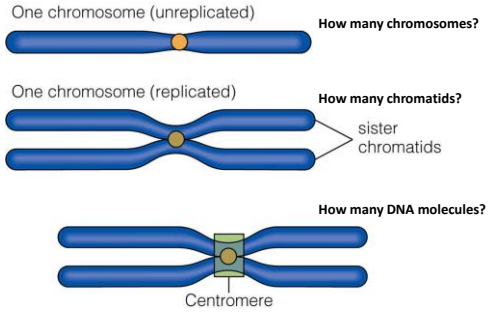


Figure 2.14

Structure of the chromosome

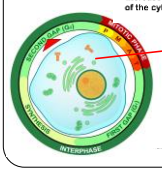


Stages of Interphase: G_2 phase

- G_2 phase – final subphase of Interphase in the cell cycle **directly preceding Mitosis**

Prolific growth ready for Mitosis

- *Organelles are produced
- *Increase volume of the cytoplasm

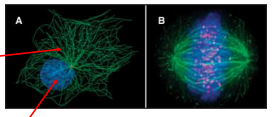


Loosely aggregated

Replicated Chromosomes indistinct and nuclear envelope intact

Microtubule formation

Interphase G_2 **Mitosis**

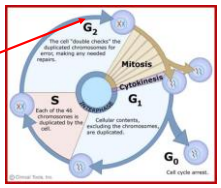


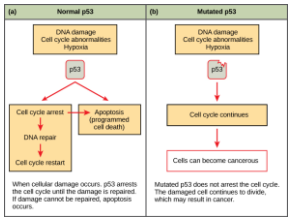
https://clinicalgate.com/macromolecular-assembly/

Stages of Interphase: G_2 restriction R point

- Final checkpoint before Mitosis

*Serves to prevent the cell from entering mitosis with genomic DNA damage



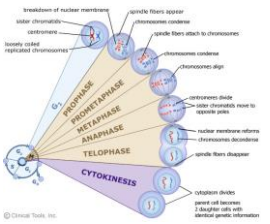


p53 protein is the cell division 'police'

https://opentextbc.ca/biology/chapter/6-3-cancer-and-the-cell-cycle/

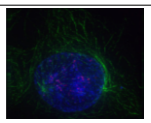
Cell cycle 2. **Mitosis**

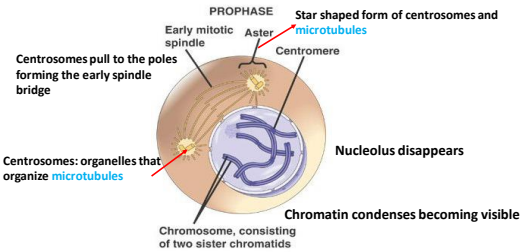
- **<u>One diploid cell</u>** divides to form **<u>two diploid cells</u>**
  - Each cell has an exact copy of the genetic information contained in the parent cell
- <u>Mitosis</u> is divided into four stages
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase



Mitosis –Prophase

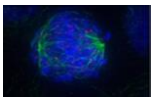
1. Changes in the nucleus
2. Changes in the cytoplasm

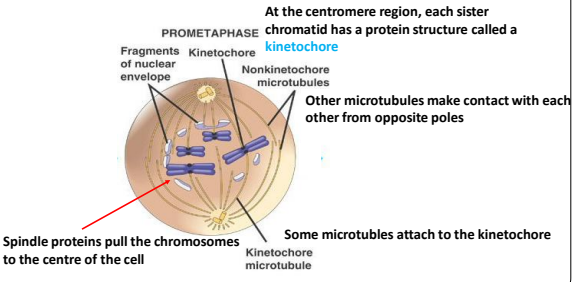




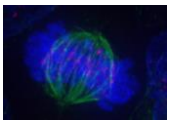
Mitosis –Prometaphase

1. Nuclear membrane breaks apart
2. Spindle fibers attach to the condensed chromosomes
3. Begin pulling the chromosomes to the center

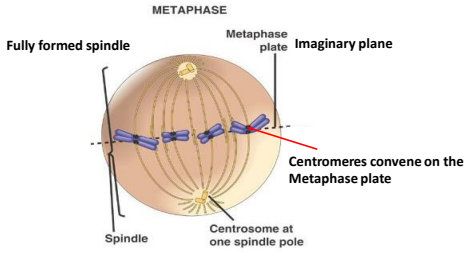




Mitosis –Metaphase

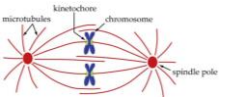


1. **Highly condensed chromosomes align in the middle of the cell**



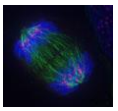
Mitosis – Spindle checkpoint

- Monitors the interaction between improperly connected kinetochores and spindle microtubules, and is maintained until kinetochores are properly attached to the spindle
- Monitors **kinetochore tension**:
  - When kinetochores are properly attached to **opposite spindle poles**, forces in the mitotic spindle generate tension

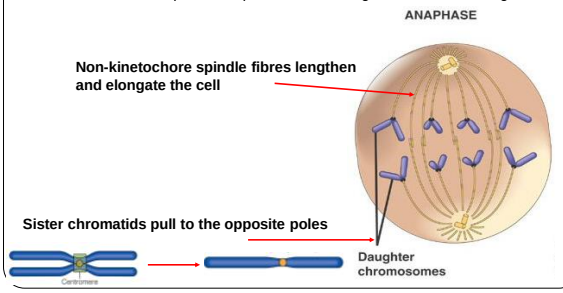


- **If activated**, the spindle checkpoint blocks anaphase entry
- **Deactivated:** correct orientation of sister chromatids

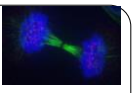
Mitosis – Anaphase



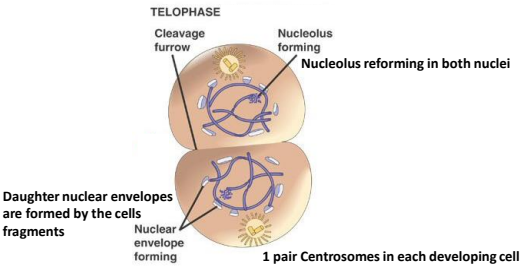
1. Chromosomes move to **opposite poles of the cell**
2. initiated by a protease known as **separase** which cleaves **cohesin**, a protein responsible for holding sister chromatids together



Mitosis –Telophase

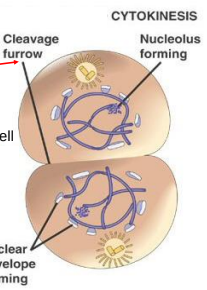


1. Two **daughter nuclei** form in the cell
2. The chromosomes unwind back into **loose chromatin**



Cytokinesis

1. **Separate phase** to mitosis
2. **Cytoplasm divides** into two daughter cells

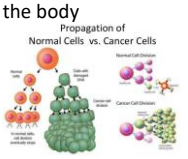


Indentation of the cell's surface that begins the progression of cleavage

Contractile ring (formed by actin and myosin filaments) tightens around the cytoplasm of the cell until the cytoplasm is pinched into two daughter cells

Mitosis in growth and cell replacement

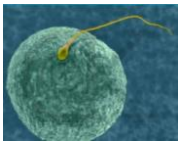
- Human somatic cells are genetically programmed to divide about 50-80 times
  - This limit allows growth to adulthood, and repairs such as wound healing
- Replicative exhausted cells undergo senescence, which is a cell cycle arrested state. They secrete proinflammatory factors to mediate their clearance from the body (macrophages)
- When it goes wrong?
  - **Cancer is a disease of the cell cycle**



https://www.slideshare.net/LiamArnadeColwill/hallmarks-of-cancer-sustained-proliferative-signaling

Meiosis: generation of genetic diversity

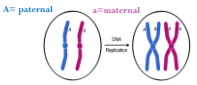
- Meiosis: A form of cell division that produces **four haploid cells** containing **only one copy** (paternal or maternal) of each chromosome
  - Meiosis I
  - Meiosis II



Humanae.tumbler.com

https://www.slideshare.net/catherinepatterson/cell-division-mitosis-and-meiosis-presentation

Terminology:



1. Homologous chromosomes

- Chromosomes exist in homologous pairs in diploid organisms
  - **Maternal and paternal:** with identical gene loci (but often different alleles)
  - **They physically pair during meiosis**

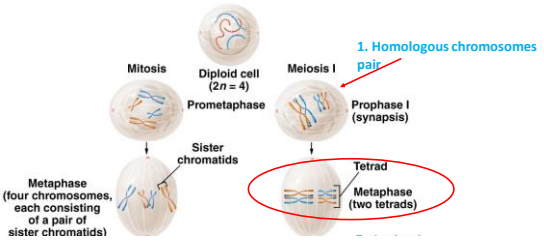
2. Assortment

- Gametes receive random combinations of maternal and paternal chromosomes (generates genetic diversity)
- Result of **meiosis I**

Meiosis:
Two vital sources of genetic variation

- 1. Crossing over: The exchange of chromosome segments between homologous regions (chromatids) in prophase I
- 2. Independent assortment of maternal and paternal chromosomes in metaphase I

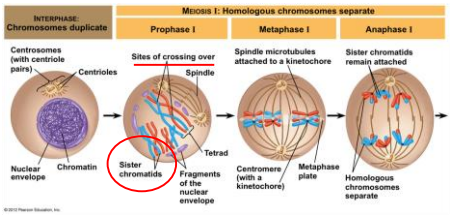
Meiosis I. Differences between mitosis



2. Homologues align on metaphase plate 'chiasmata'

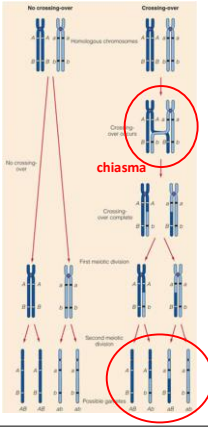
Meiosis I

1. In meiosis I, members of **a pair of homologous chromosomes** physically associate
   - **Crossing over occurs, which increases the genetic diversity in the gametes.**



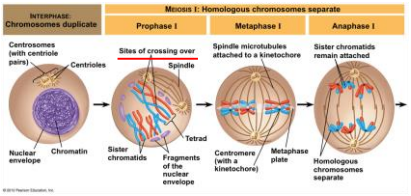
Prophase I. Crossing over

- Exchange of genetic material between homologous chromosomes that results in **recombinant** chromosomes
- Homologous regions (chromatids) break and then reconnect to the other chromosome
- Results in a new arrangement of maternal and paternal alleles on the same chromosome



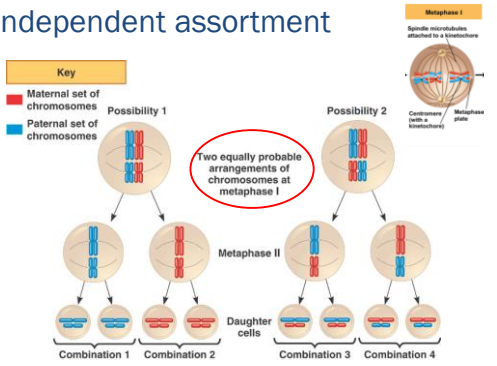
Meiosis I. Independent assortment

Meiosis I produces cells that contain one duplicated member of each chromosome pair



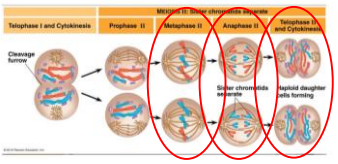
1. Homologous chromosomes line up **randomly** at **metaphase**
2. Random combinations of maternal and paternal homologues separate at **anaphase**

Independent assortment



Does not occur (usually) in eukaryotic mitosis, only meiosis

Meiosis II



Metaphase II

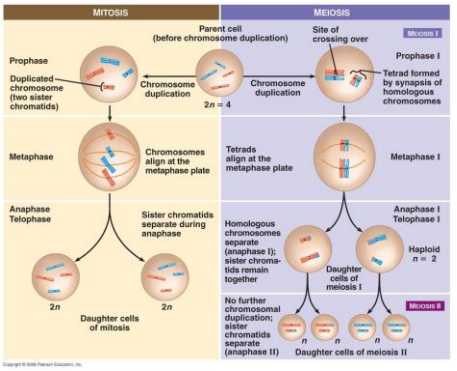
Unpaired chromosomes align at the cell's middle
There is no synthesis (replication) of chromosomes before meiosis II.
Therefore, only the remaining one replicated chromosome

Anaphase II

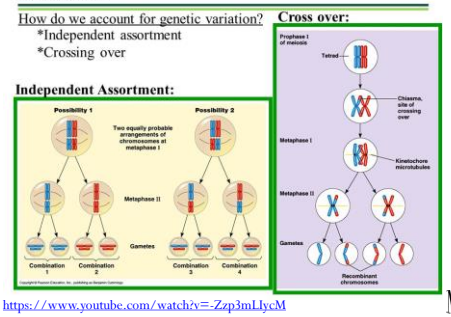
Centromeres divide and daughter chromosomes move to opposite poles

Meiosis produces four haploid cells (n)
In humans, the haploid number is 23

Comparing mitosis and meiosis



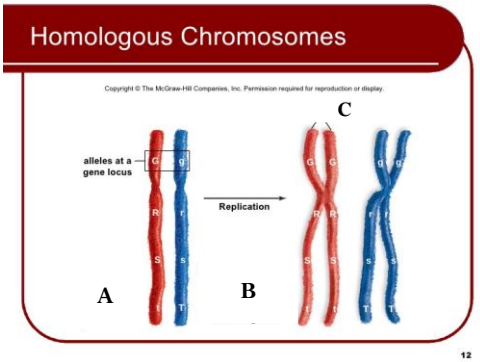
Independent Assortment and Crossing Over



https://www.youtube.com/watch?v=-Zzp3mLlycM

4.20 min

Quiz: What does A, B and C stand for?



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Review questions

- What is the different between chromatin and chromatids and at what stages in the cell cycle do they exist?
- At what stage of meiosis does crossing over and independent assortment occur? Do these events occur in mitosis, why?
- How many chromosomes are present at each cell cycle stage?
- How many chromatids?
- How many copies of the same gene (somatic cells chromosomes only)? (i.e. how many molecules of DNA?)
- What are the two main sources of genetic variation produced by meiosis?

Prepare a glossary

Chromosome

Chromatin

Chromatid

Euchromatin

Hetrochromatin

Cell cycle stages (Interphase, Mitosis, Meiosis, Synthesis, etc)

Centromere, spindle fibres, kinetochore

Independent assortment

Crossing over