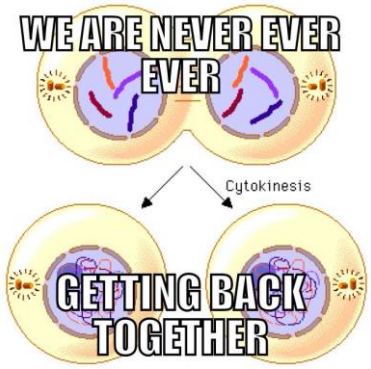
Chromosomes
Mitosis and Meiosis

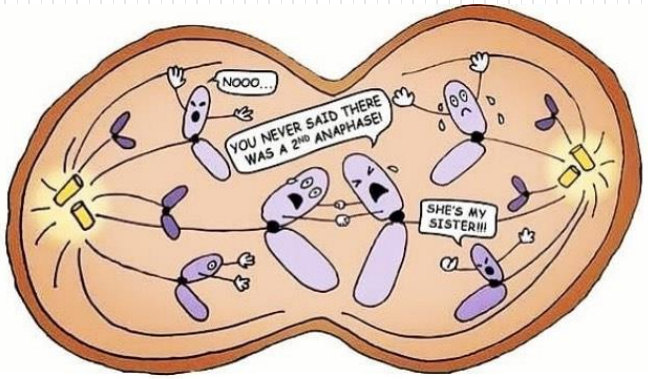
Class 2

SLE254 Genetics and Genomics

Chapter 2 Concepts of Genetics (12th Ed)

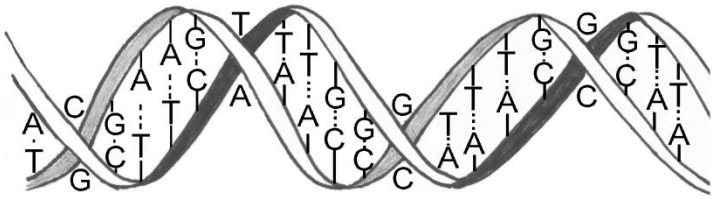
Pages 50-71 Ch2



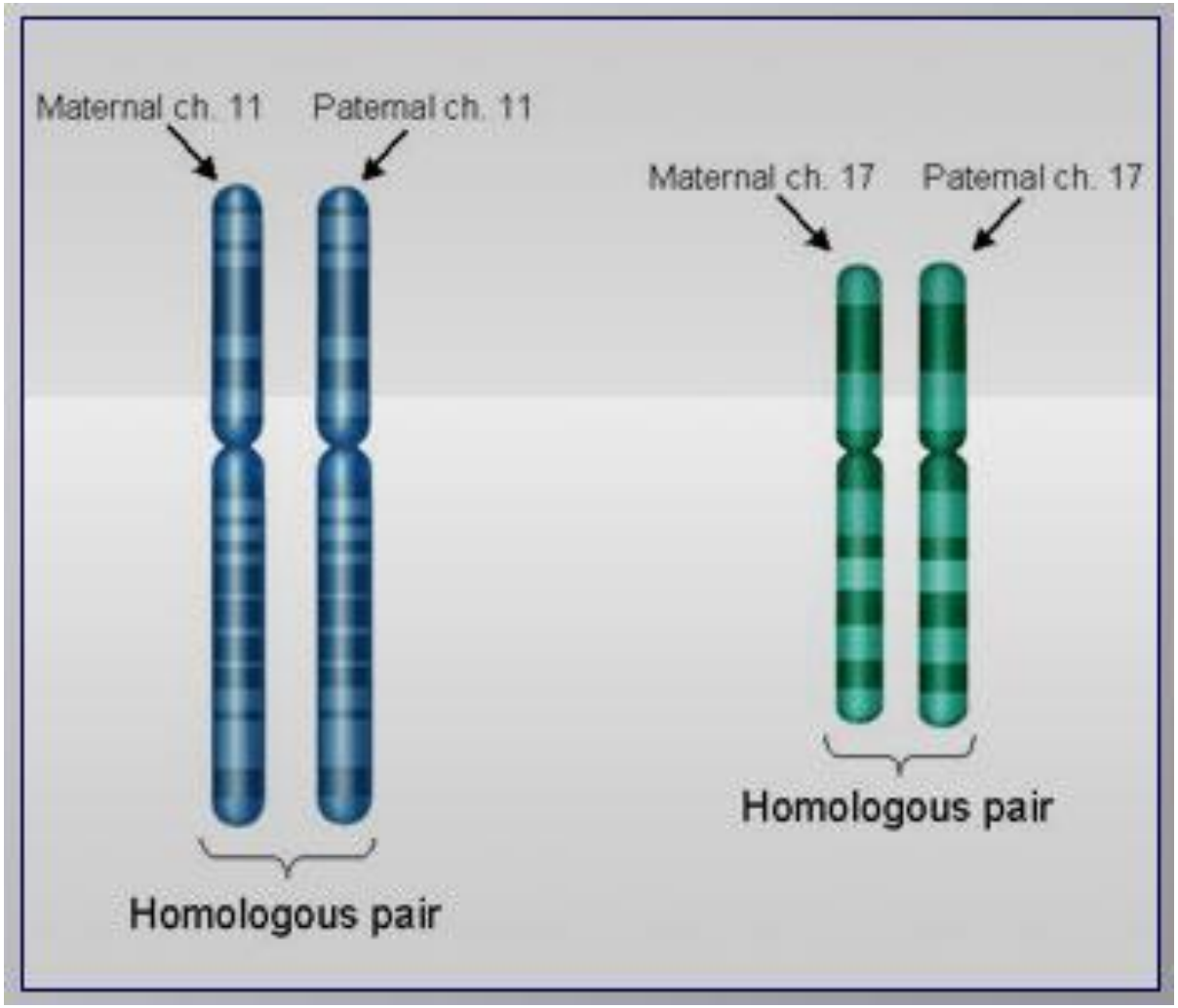


Terminology

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

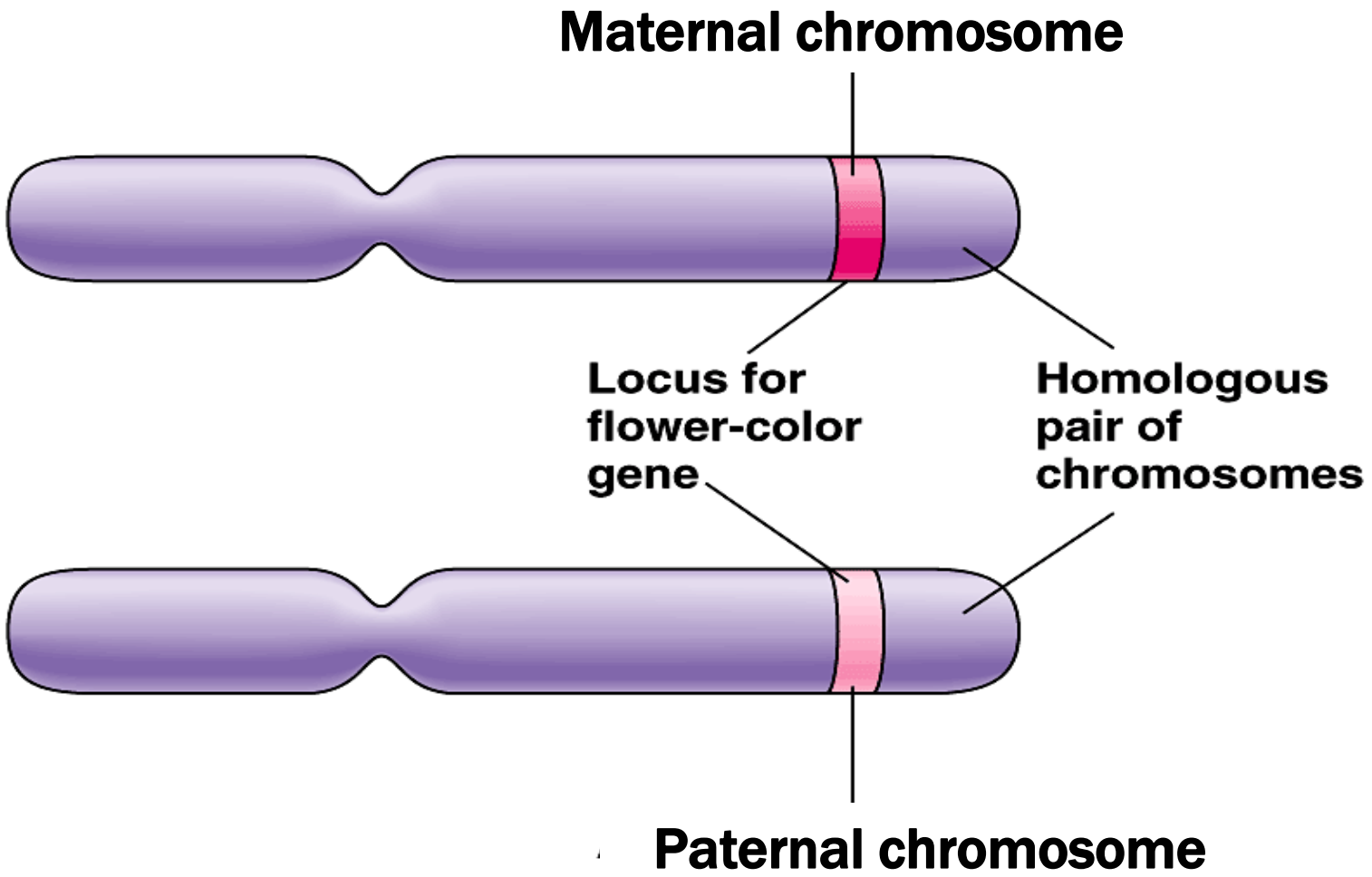


Homologous Chromosomes

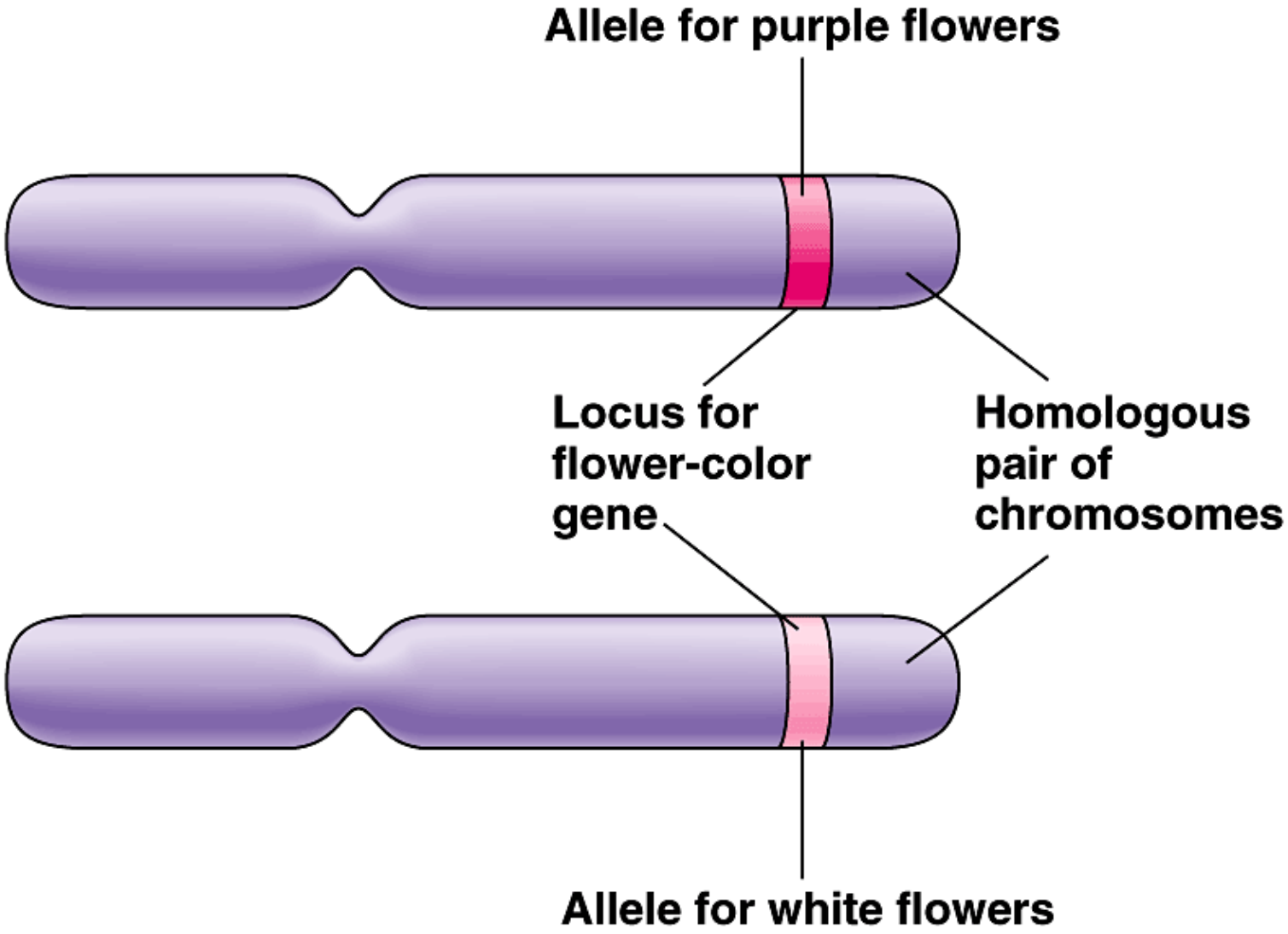


During meiosis homologs pair together

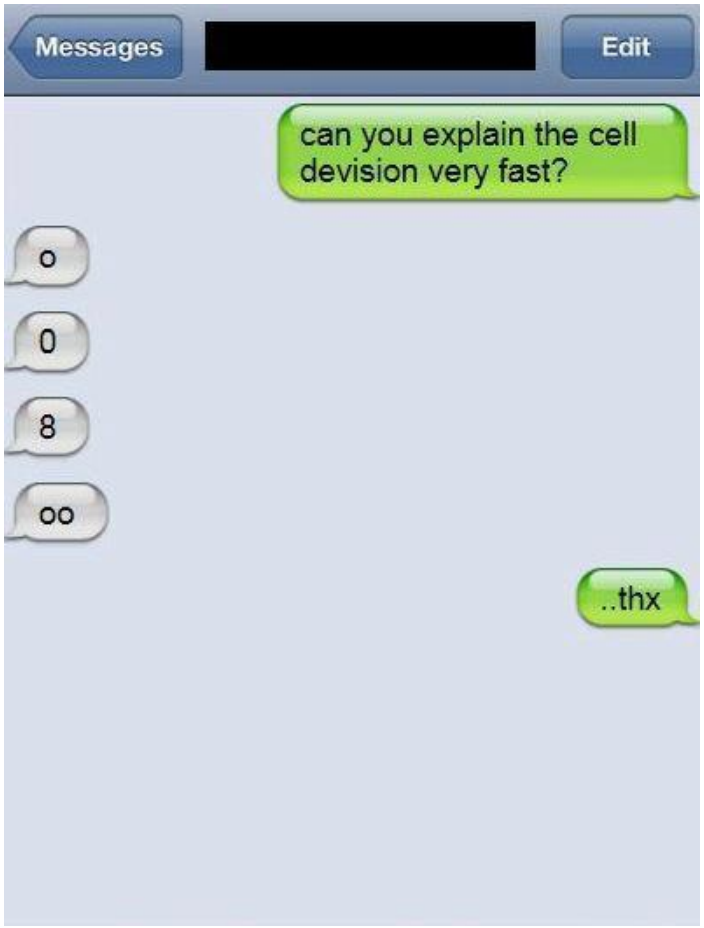
Locus – position of allele on a chromosome

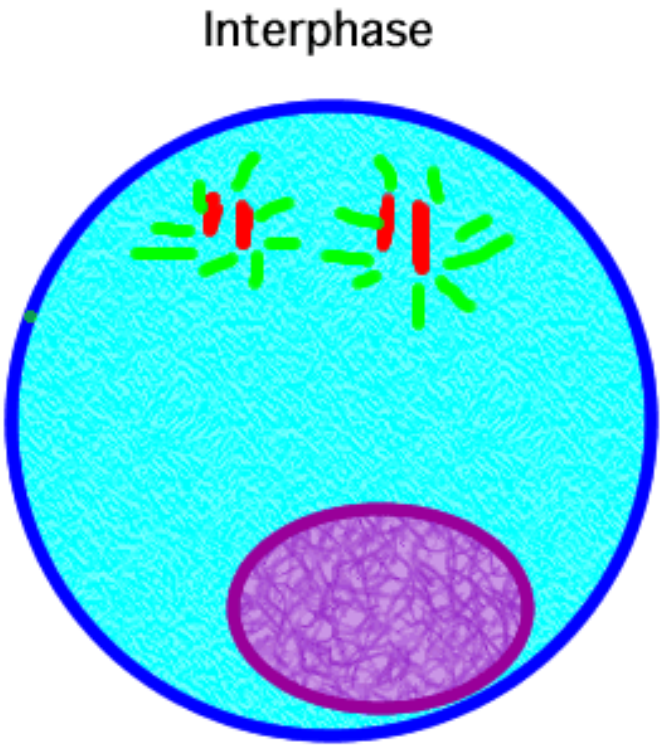


Allele – alternative DNA sequence at the same locus



Cell division and the cell cycle





http://www2.amersol.edu.pe/class11/_11pcugli/7th/science/images/cells.gif

http://24.media.tumblr.com/tumblr_m9l8b7gMNk1qibv8fo1_400.jpg

The cell cycle

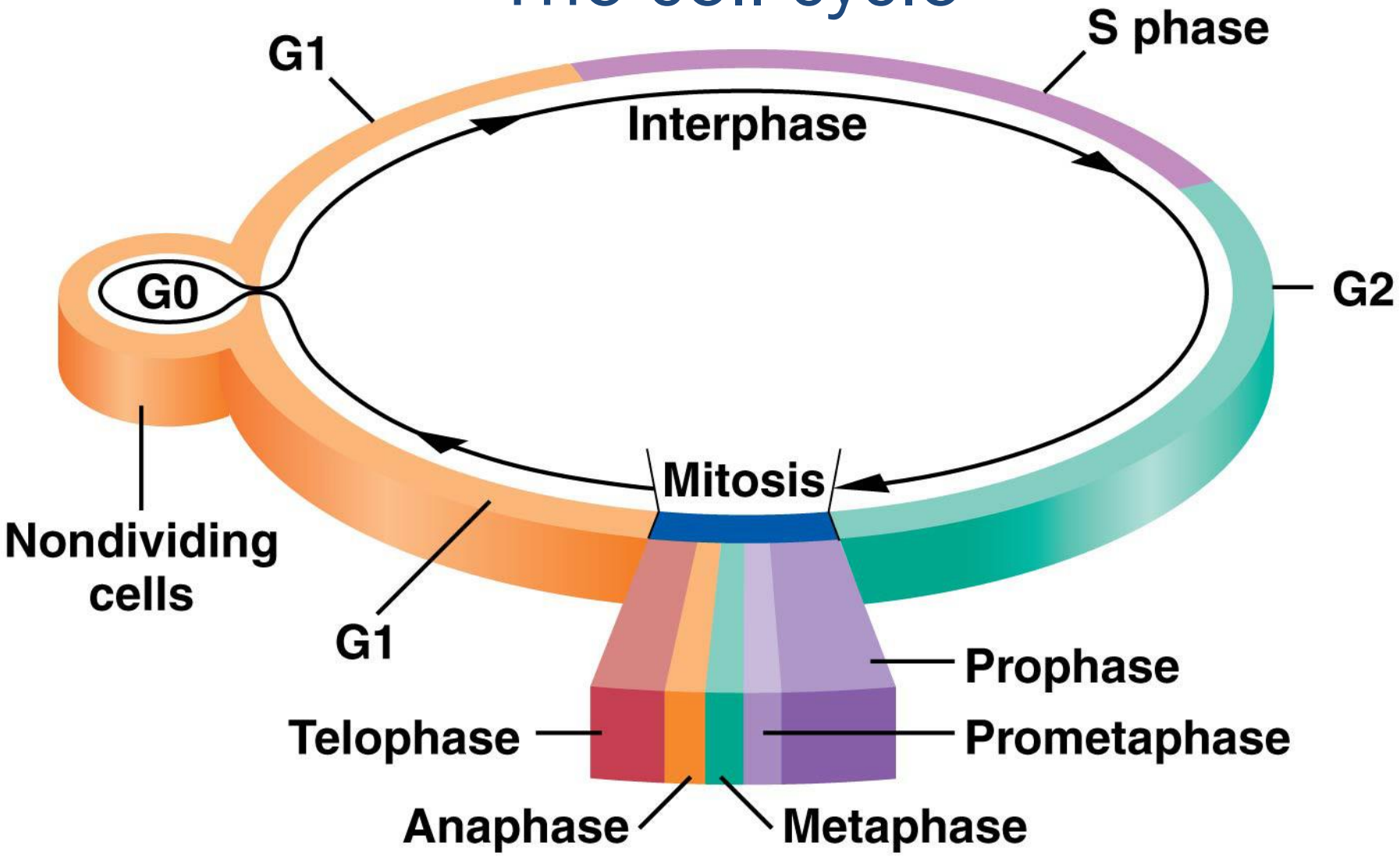


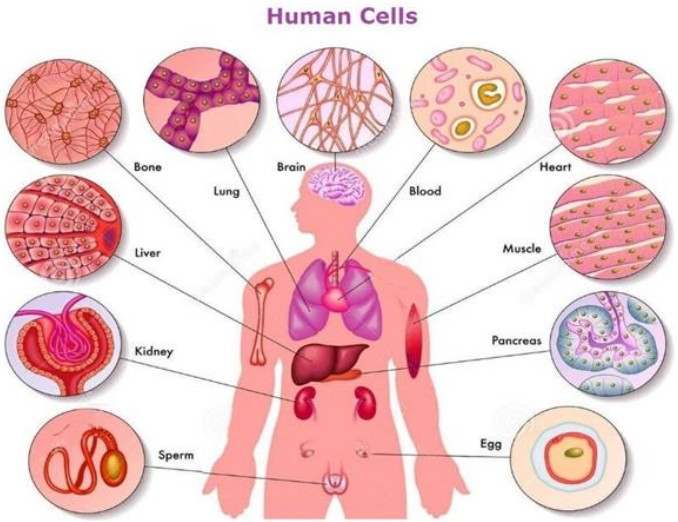
Figure 2-5

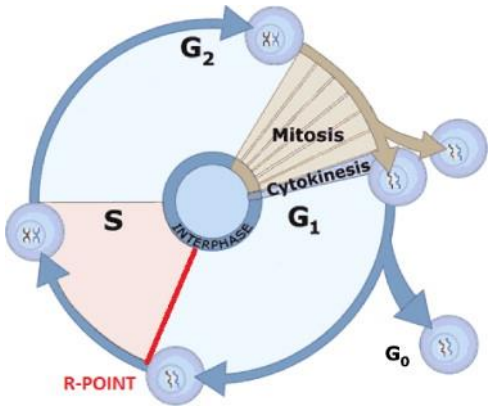
Cell cycle 1. **Interphase**

- **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



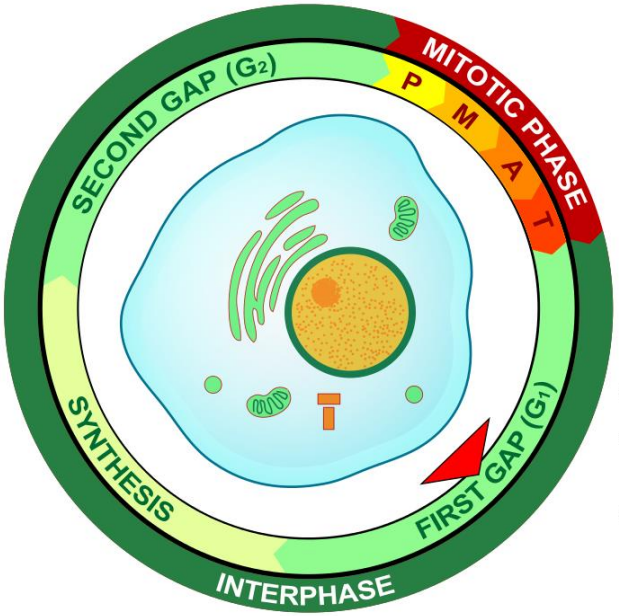


Stages of Interphase: Gap 1

- **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



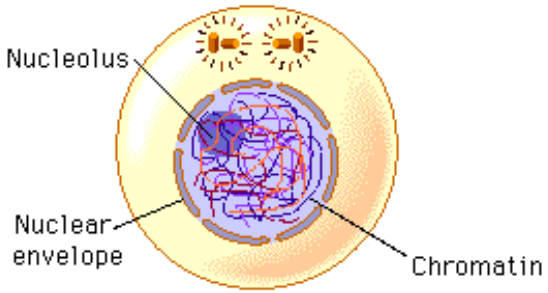
*Protein synthesis

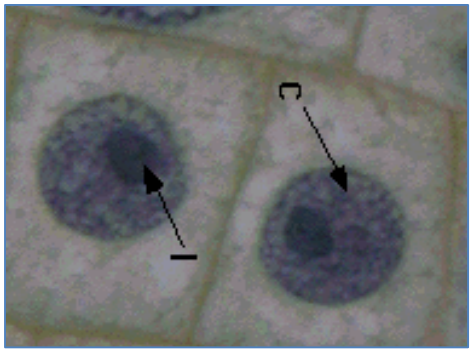
*Organelles are produced

*Increase volume of the cytoplasm

Chromosomes in Interphase

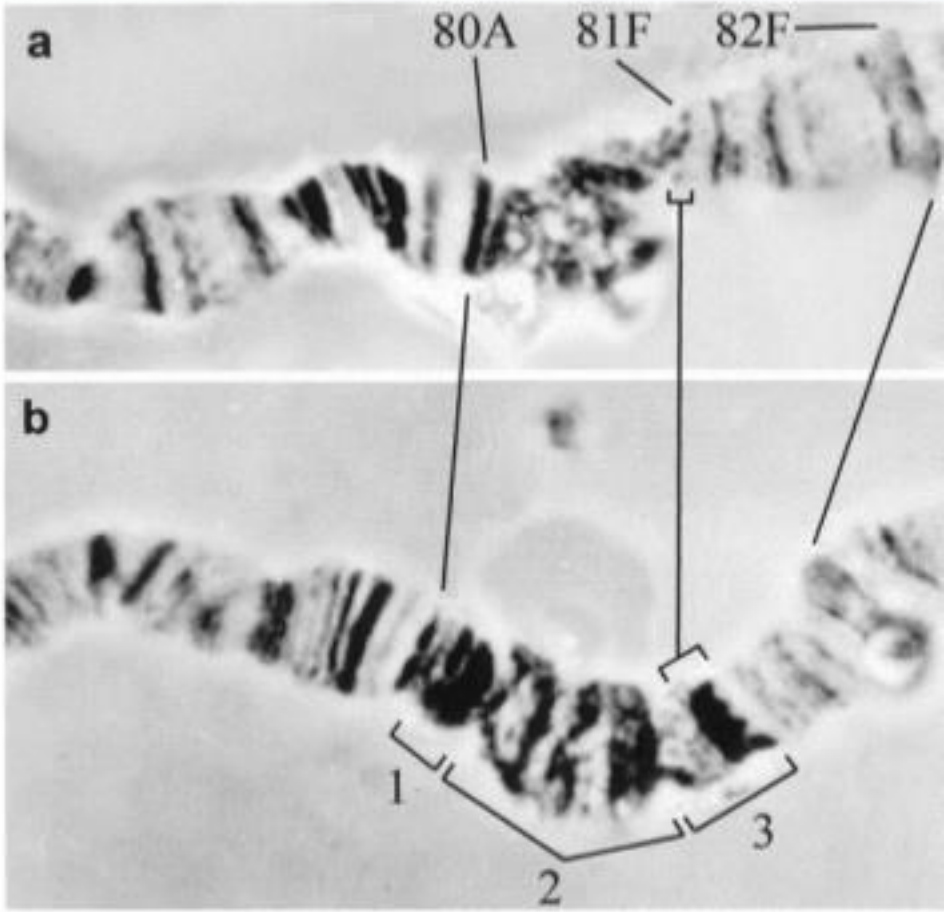
- The DNA in a G_1 diploid eukaryotic cell is **2n**, meaning there are **two sets of chromosomes** present in the cell
- The genetic material exists in loose form **chromatin**
  - The structure of chromatin during interphase is optimised to allow easy access of transcription and DNA repair factors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





Interphase Chromatin

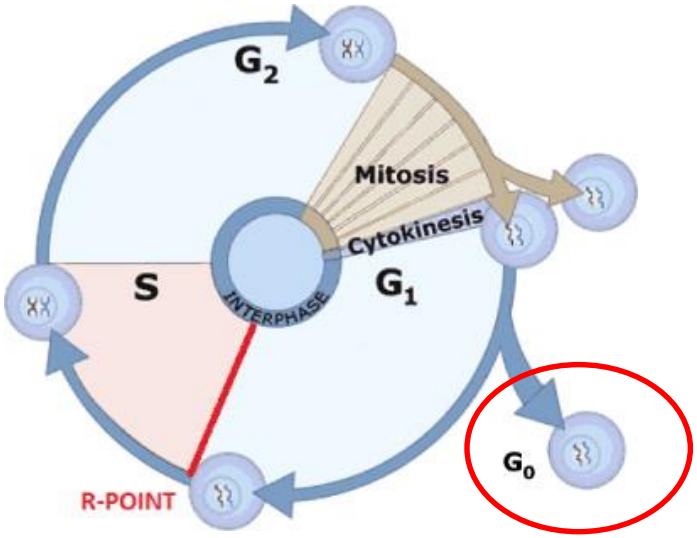
- Different levels of packing on various regions of the same chromosome
- Euchromatin: loosely packed region on chromatin, active transcription
- Heterochromatin: densely packed region on chromatin, inactivated



Eu = true; Hetero = different

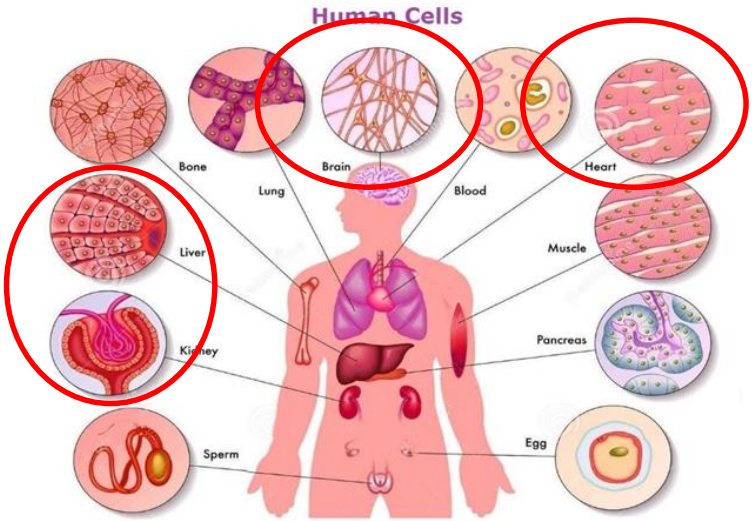
Stages of Interphase: G_0 phase

- 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

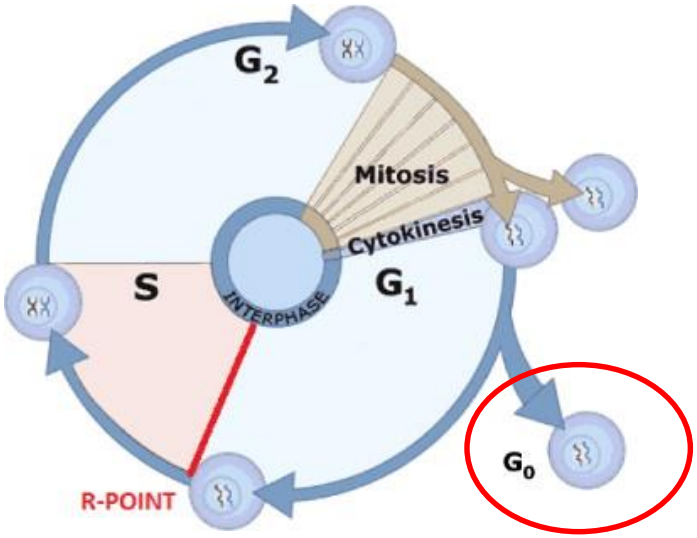


Semi permanent

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

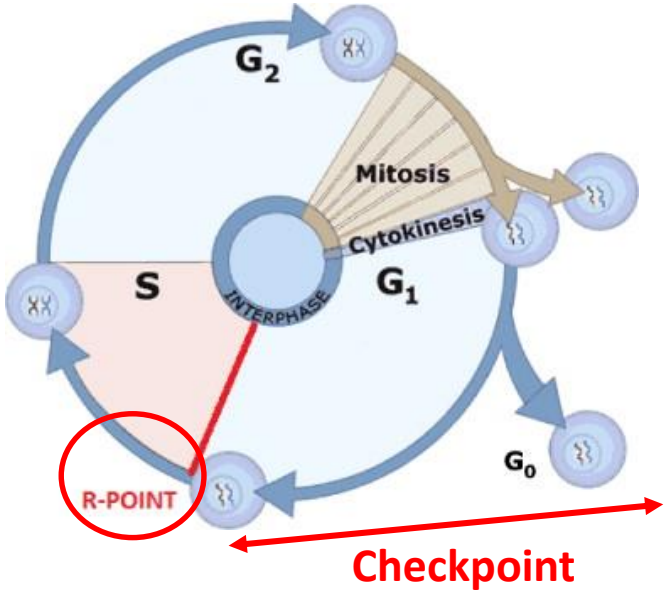
Epithelia line tissues, organs: skin

Cells	Location	Function
Simple squamous epithelium	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium	In ducts and secretory portions of small glands and in kidney tubules	Secretes and absorbs
Simple columnar epithelium	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (nonciliated tissues) are in the digestive tract, bladder	Absorbs; it also secretes mucous and enzymes
Pseudostratified columnar epithelium	Ciliated tissue lines the trachea and much of the upper respiratory tract	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium	Lines the esophagus, mouth, and vagina	Protects against abrasion
Stratified cuboidal epithelium	Sweat glands, salivary glands, and the mammary glands	Protective tissue
Stratified columnar epithelium	The male urethra and the ducts of some glands	Secretes and protects
Transitional epithelium	Lines the bladder, uretha, and the ureters	Allows the urinary organs to expand and stretch

Stages of Interphase: restriction (R) point

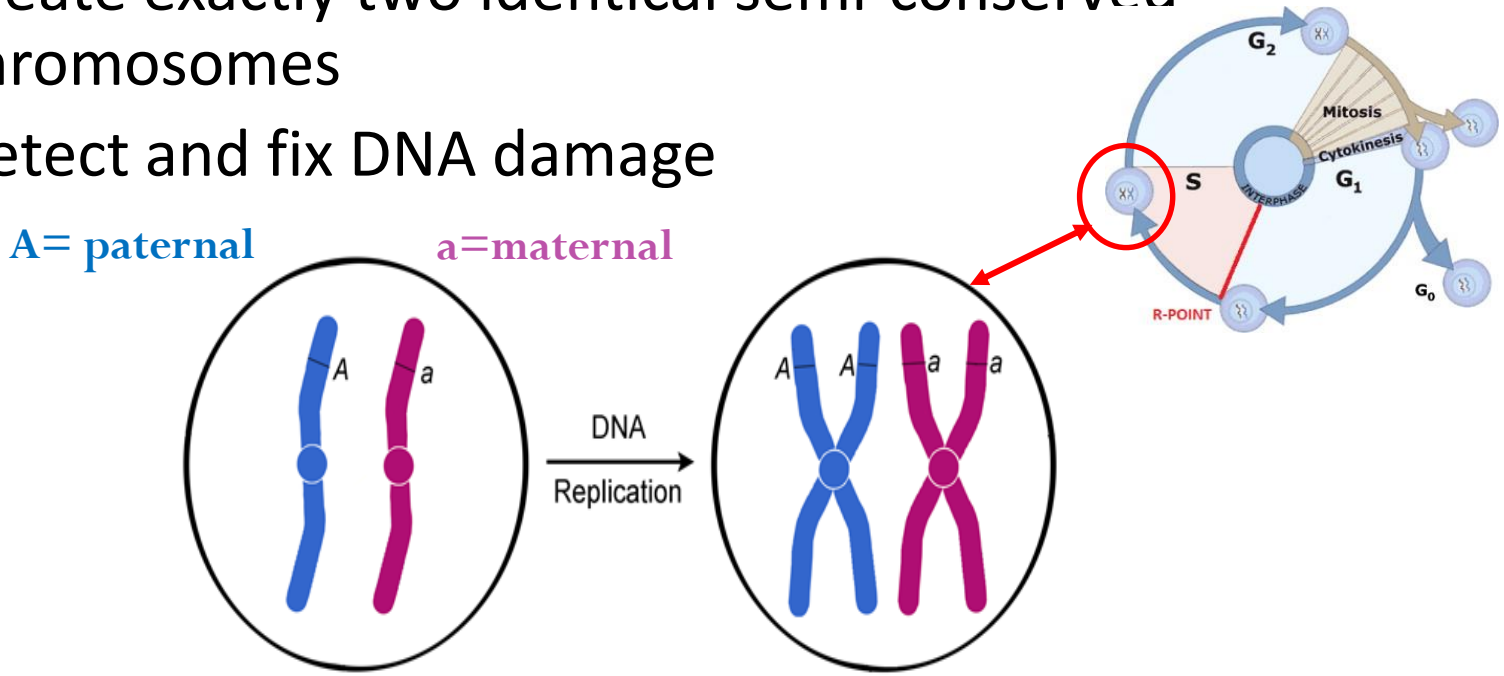
- The restriction (R) point is present at the end of G_1 phase

- 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

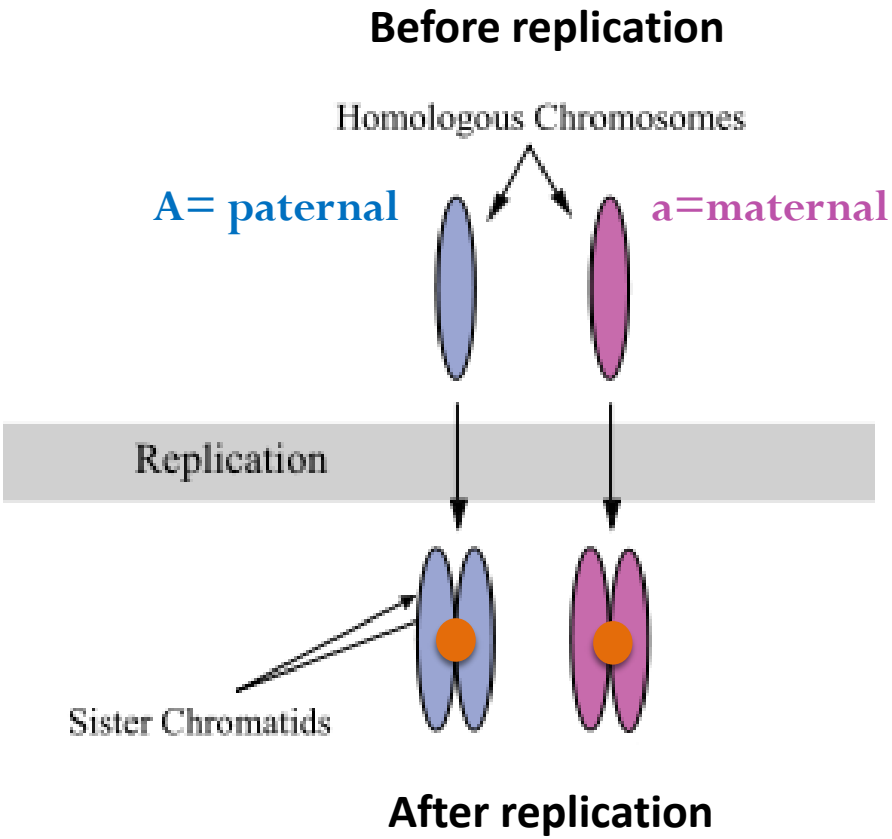


Doubling of DNA but the cell is still **2n**, meaning there are still two sets of chromosomes

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

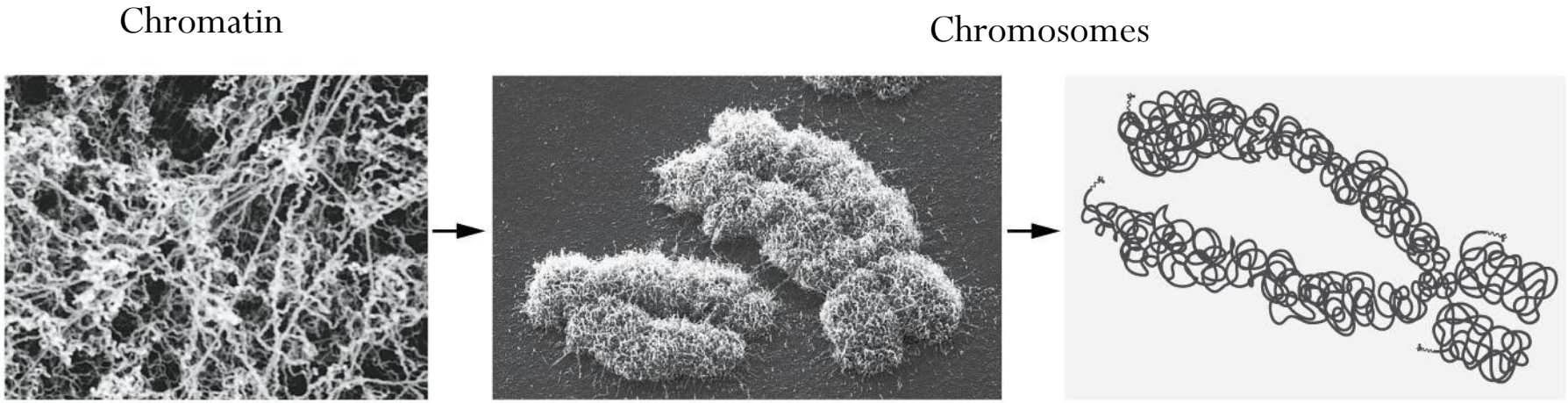


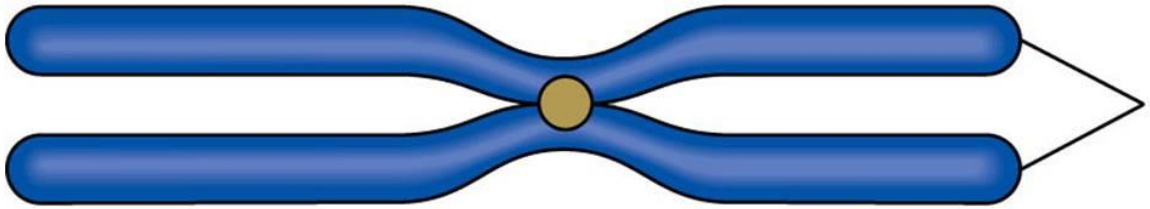
Figure 2.14

Structure of the chromosome

One chromosome (unreplicated)

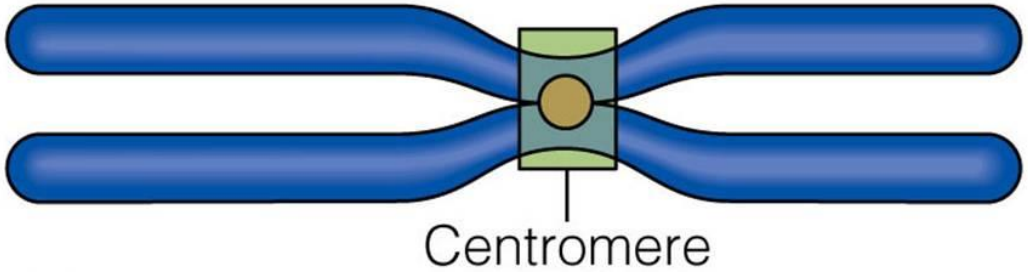
How many chromosomes?

One chromosome (replicated)



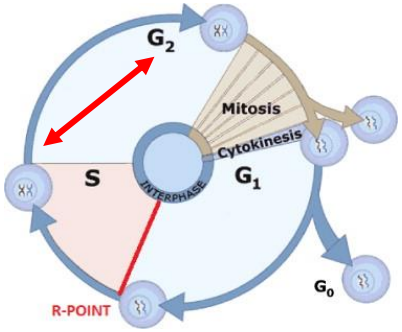
How many chromatids?

How many DNA molecules?



Stages of Interphase: G_2 phase

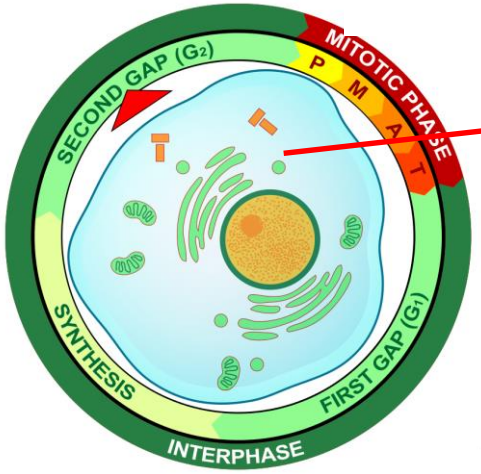
- **G_2 phase** – final subphase of Interphase in the cell cycle **directly preceding Mitosis**



Prolific growth ready for Mitosis

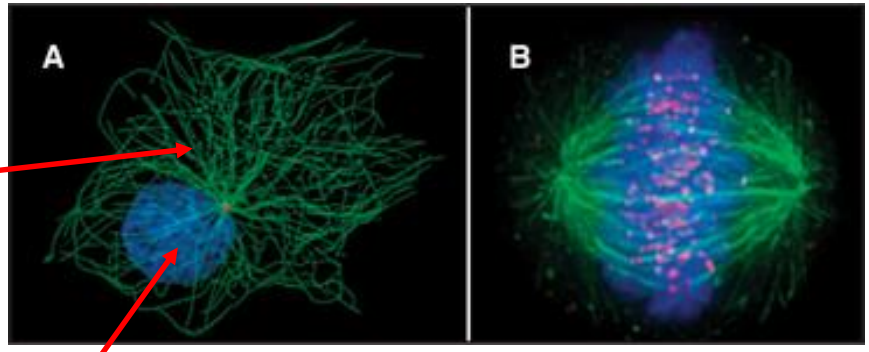
*Organelles are produced

*Increase volume of the cytoplasm



Microtubule formation

Interphase G_2 **Mitosis**



Loosely aggregated

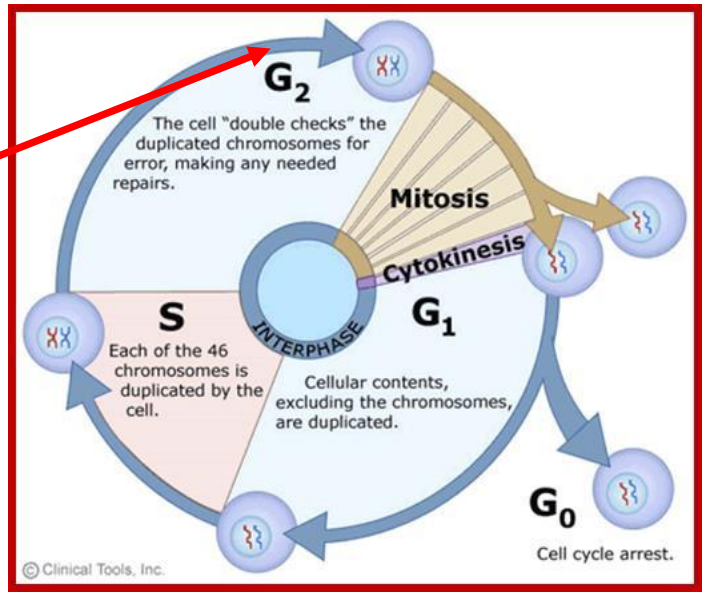
Replicated Chromosomes indistinct and nuclear envelope intact

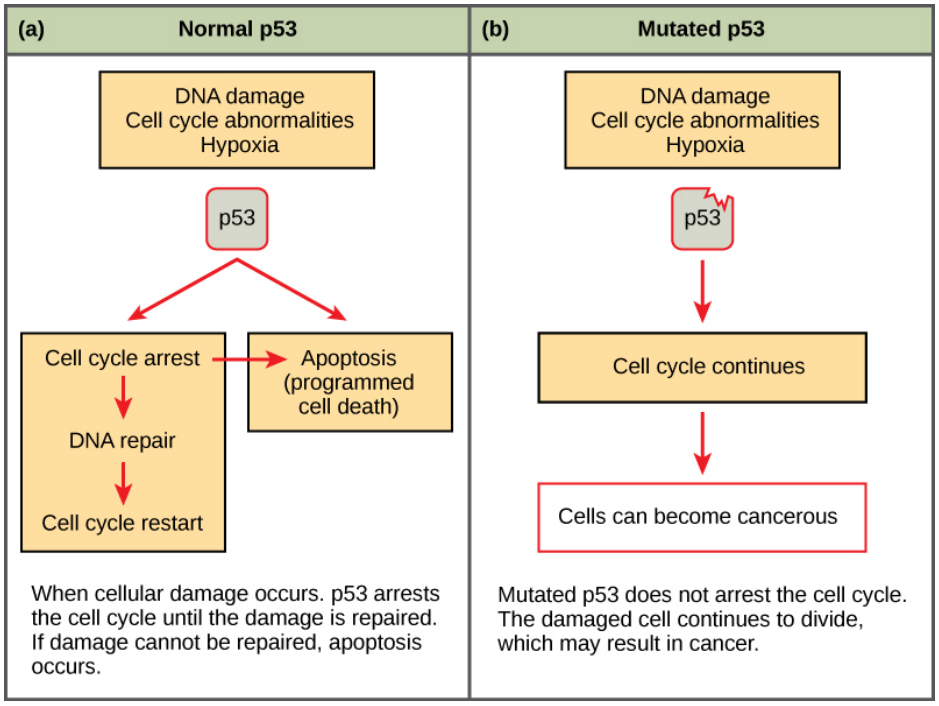
https://clinicalgate.com/macromolecular-assembly/

Stages of Interphase: G_2 restriction R point

- Final checkpoint before Mitosis

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





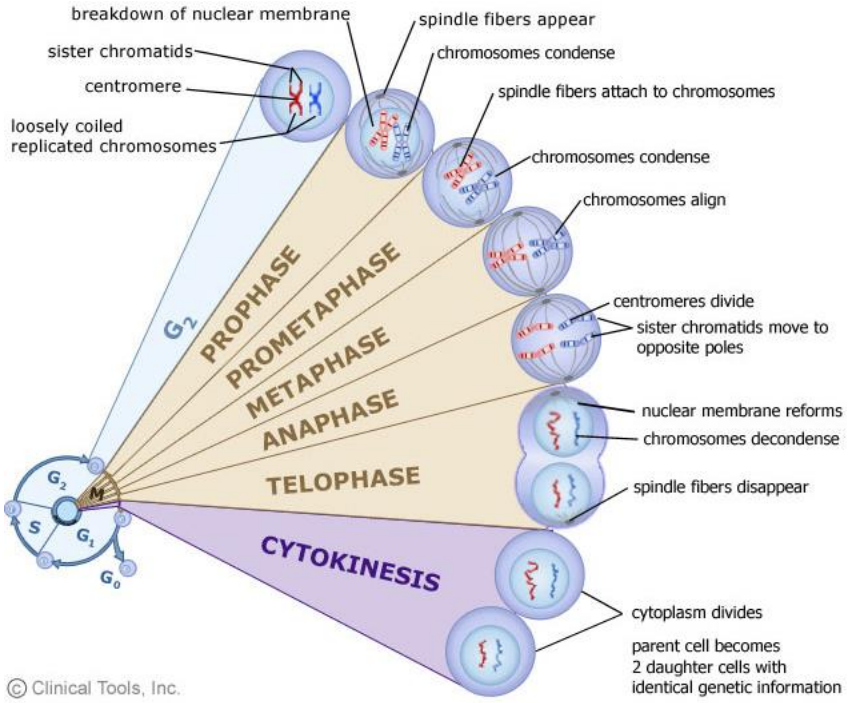
p53 protein is the cell division 'police'

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

Cell cycle 2. **Mitosis**

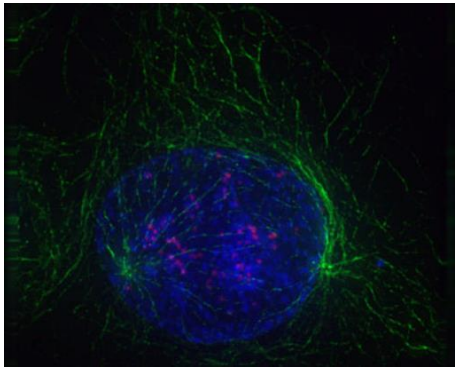
- **<u>One diploid cell</u>** divides to form **<u>two diploid cells</u>**
  - Each cell has an exact copy of the genetic information contained in the parent cell

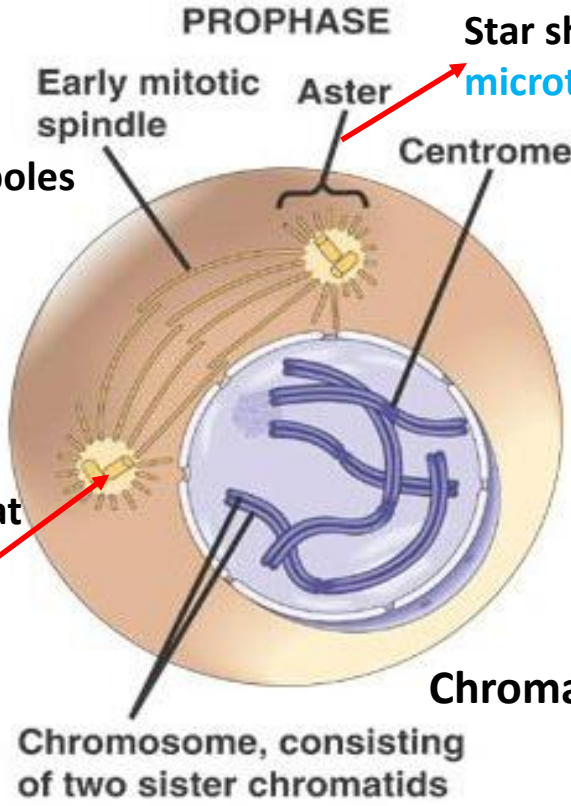
- <u>Mitosis</u> is divided into four stages
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase



Mitosis – Prophase

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





Star shaped form of centrosomes and microtubules

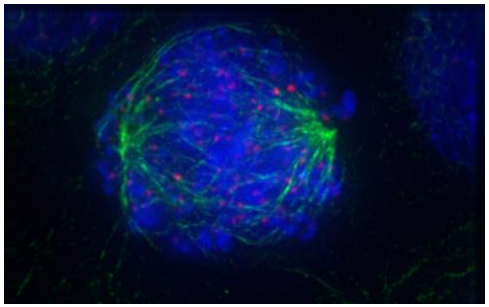
Centrosomes pull to the poles forming the early spindle bridge

Centrosomes: organelles that organize microtubules

Nucleolus disappears

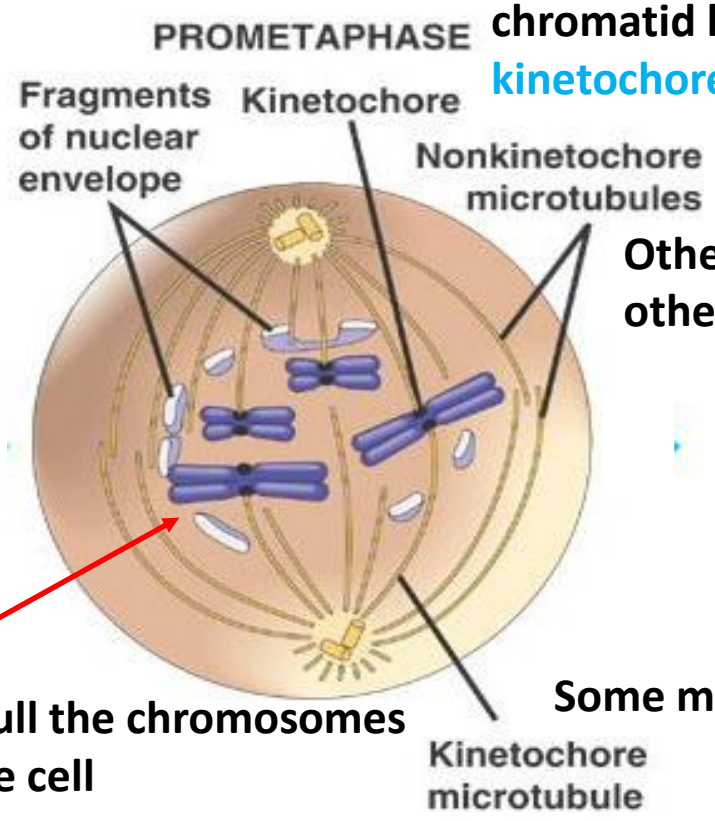
Chromatin condenses becoming visible

Mitosis – Prometaphase



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

At the centromere region, each sister chromatid has a protein structure called a kinetochore

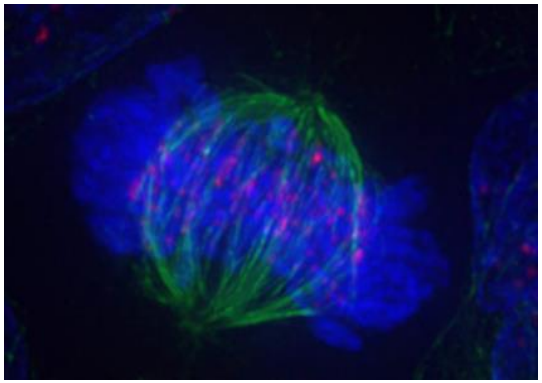


Other microtubules make contact with each other from opposite poles

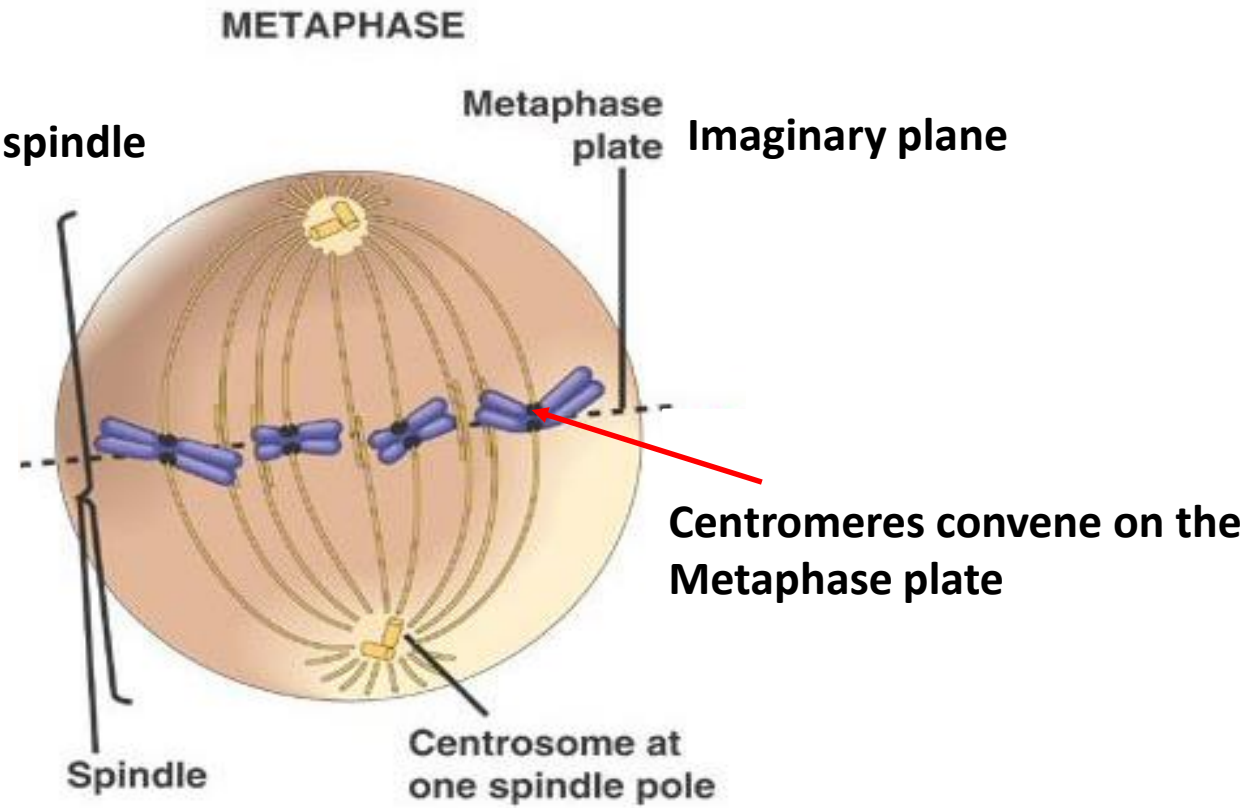
Spindle proteins pull the chromosomes to the centre of the cell

Some microtubles attach to the kinetochore

Mitosis – Metaphase



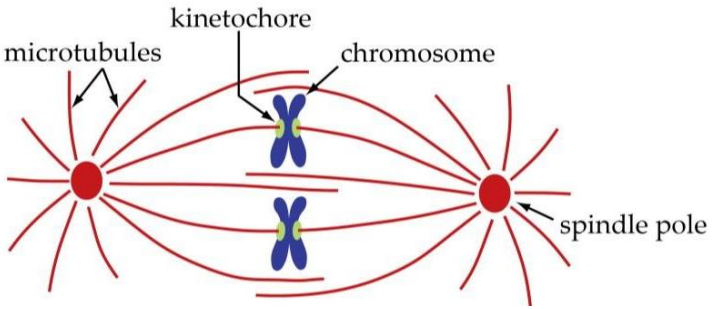
1. **Highly condensed chromosomes align in the middle of the cell**



Mitosis – Spindle checkpoint

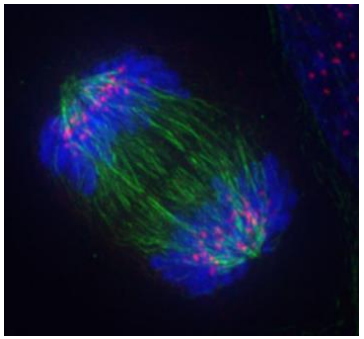
- Monitors the interaction between improperly connected kinetochores and spindle microtubules, and is maintained until kinetochores are properly attached to the spindle

- Monitors **kinetochore tension**:
  - When kinetochores are properly attached to **opposite spindle poles**, forces in the mitotic spindle generate tension



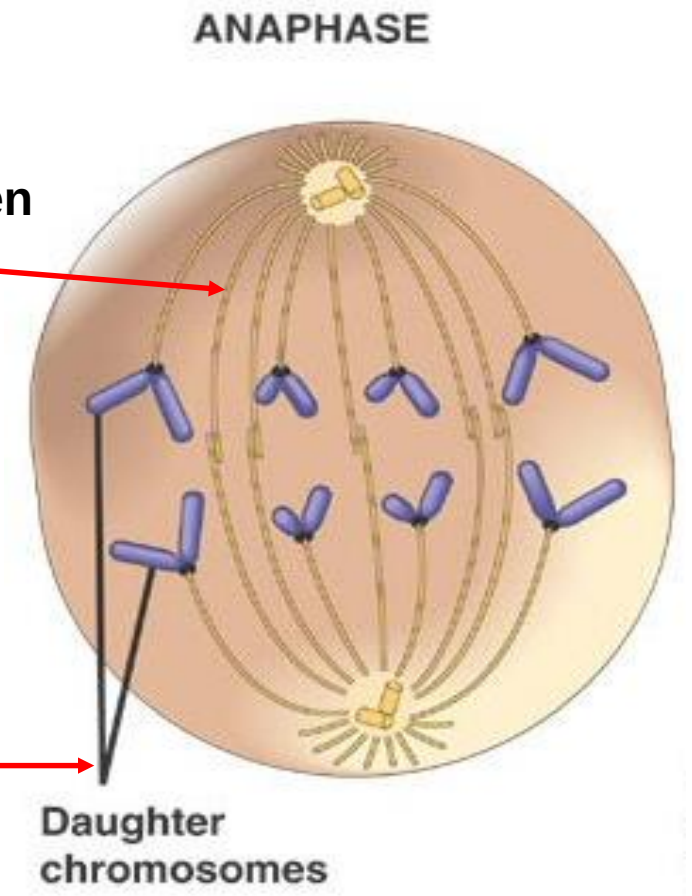
- **If activated**, the spindle checkpoint blocks anaphase entry
- **Deactivated:** correct orientation of sister chromatids

Mitosis – Anaphase

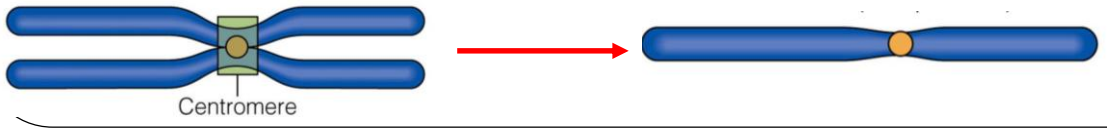


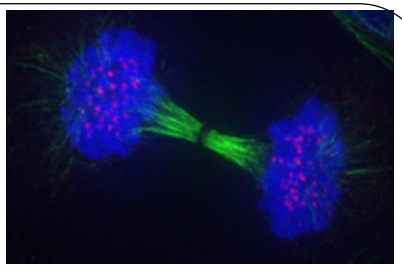
1. Chromosomes move to **opposite poles of the cell**
2. initiated by a protease known as **separase** which cleaves **cohesin**, a protein responsible for holding sister chromatids together

Non-kinetochore spindle fibres lengthen and elongate the cell



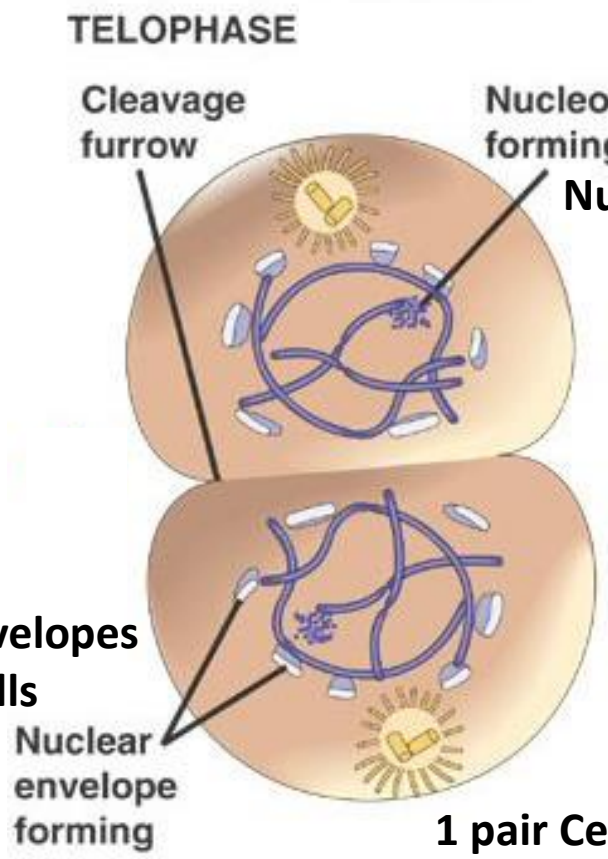
Sister chromatids pull to the opposite poles





Mitosis – Telophase

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

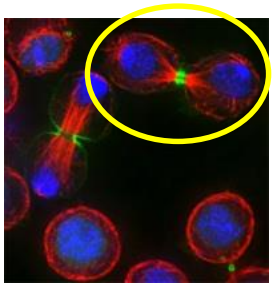


Nucleolus reforming in both nuclei

Daughter nuclear envelopes are formed by the cells fragments

1 pair Centrosomes in each developing cell

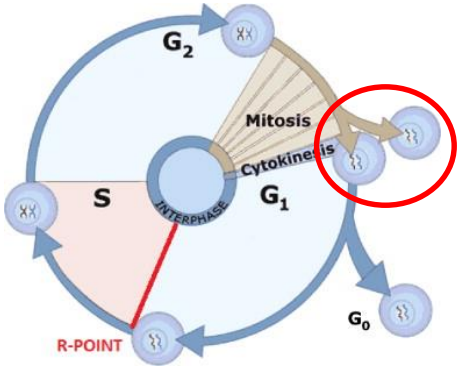
Cytokinesis

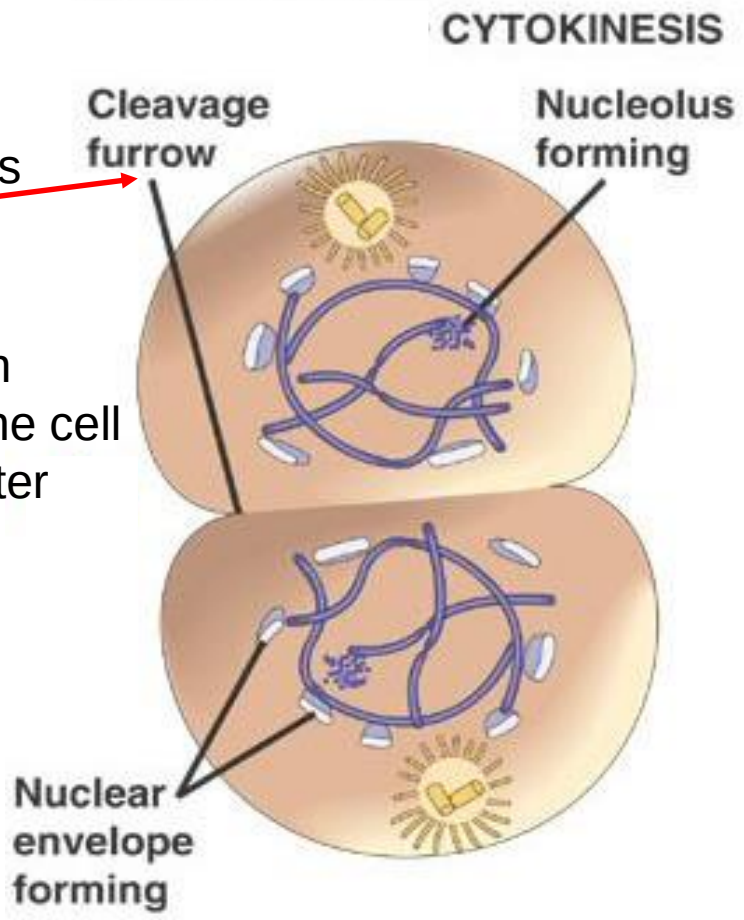


1. **Separate phase** to mitosis
2. **Cytoplasm divides** into two daughter cells

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

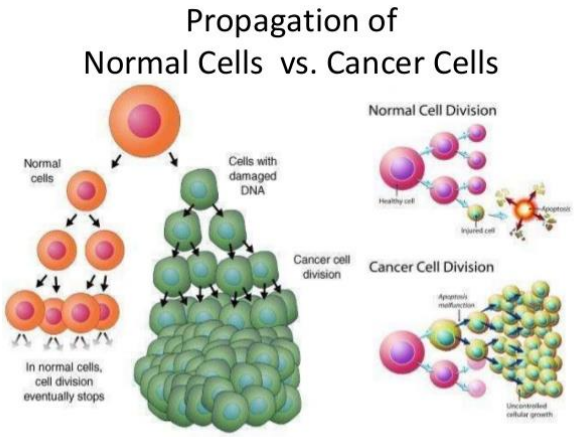




Mitosis in growth and cell replacement

- Human somatic cells are genetically programmed to divide about 50-80 times
  - This limit allows growth to adulthood, and repairs such as wound healing

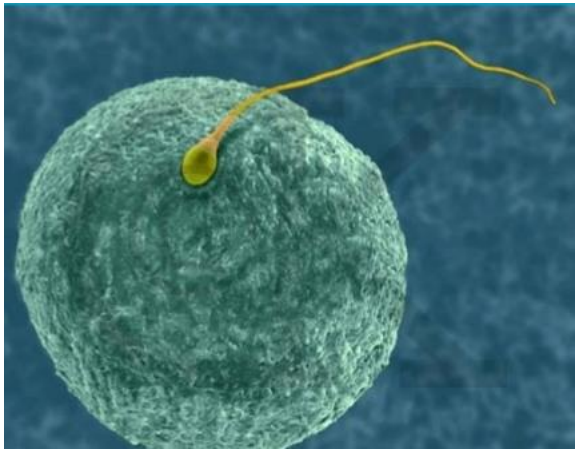
- Replicative exhausted cells undergo senescence, which is a cell cycle arrested state. They secrete proinflammatory factors to mediate their clearance from the body (macrophages)
- When it goes wrong?
  - **Cancer is a disease of the cell cycle**



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

Meiosis: generation of genetic diversity

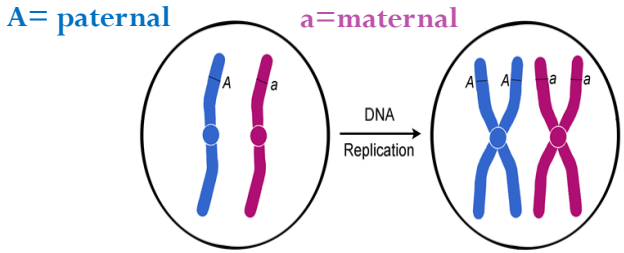
- Meiosis: A form of cell division that produces **four haploid cells** containing **only one copy** (paternal or maternal) of each chromosome
  - Meiosis I
  - Meiosis II



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

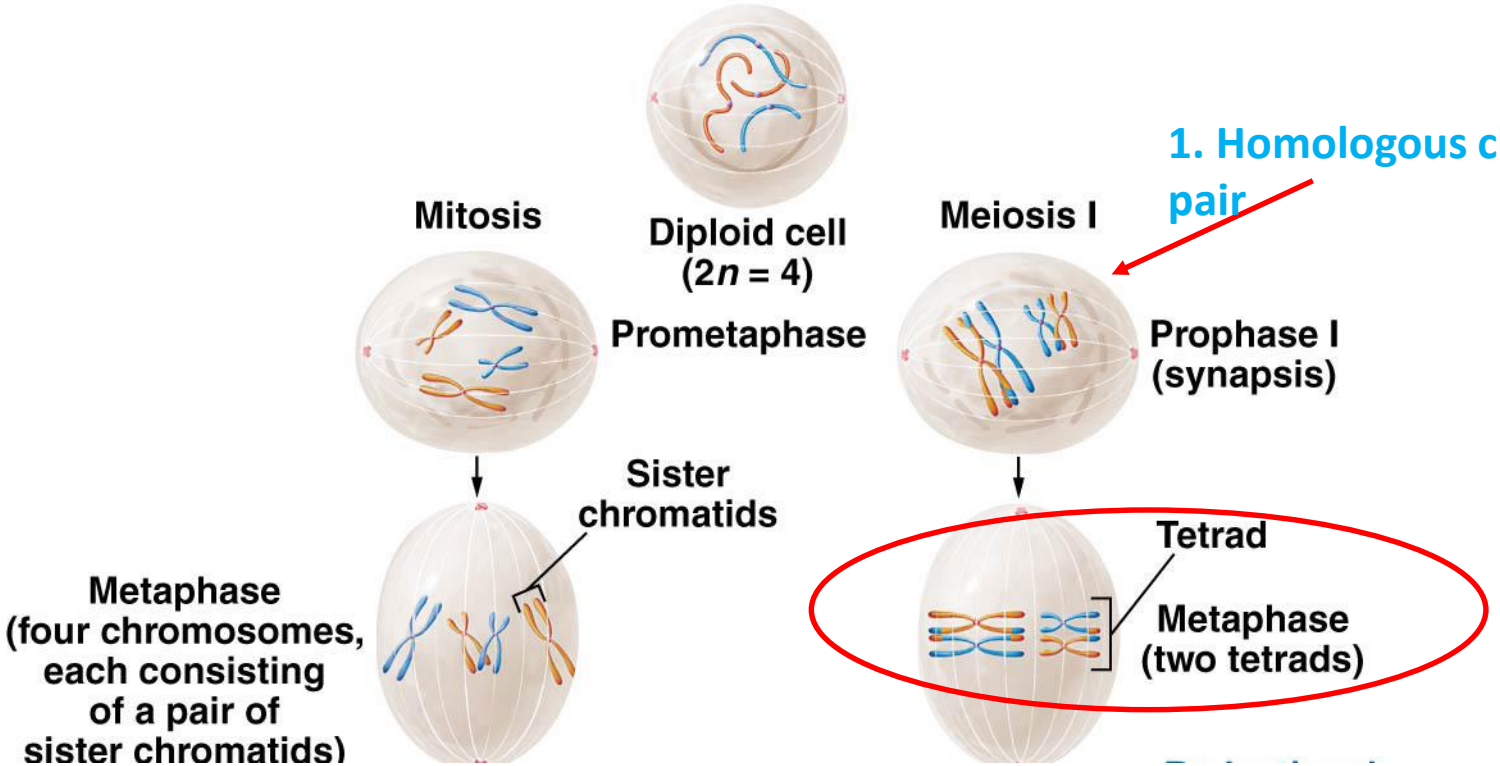
- Gametes receive random combinations of maternal and paternal chromosomes (generates genetic diversity)
- Result of **meiosis I**

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



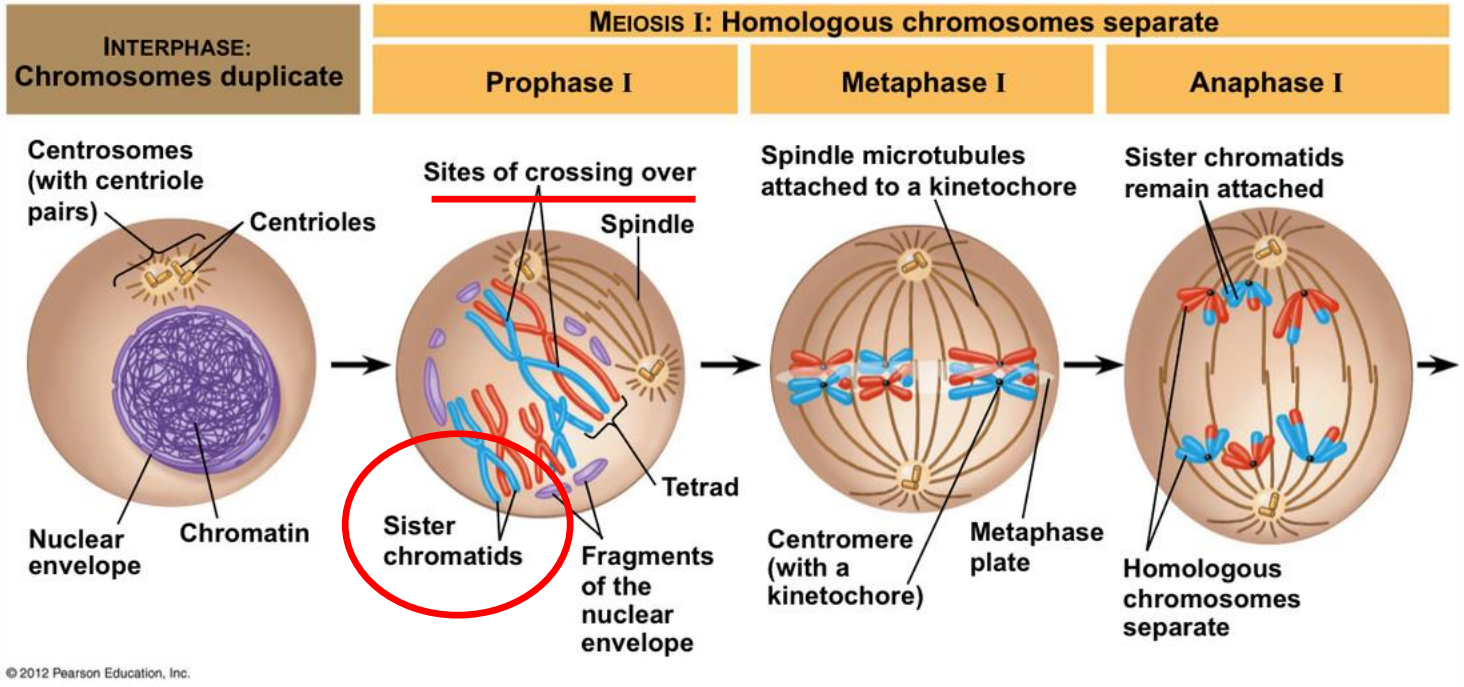
1. Homologous chromosomes pair

2. Homologues align on metaphase plate 'chiasmata'

Meiosis I

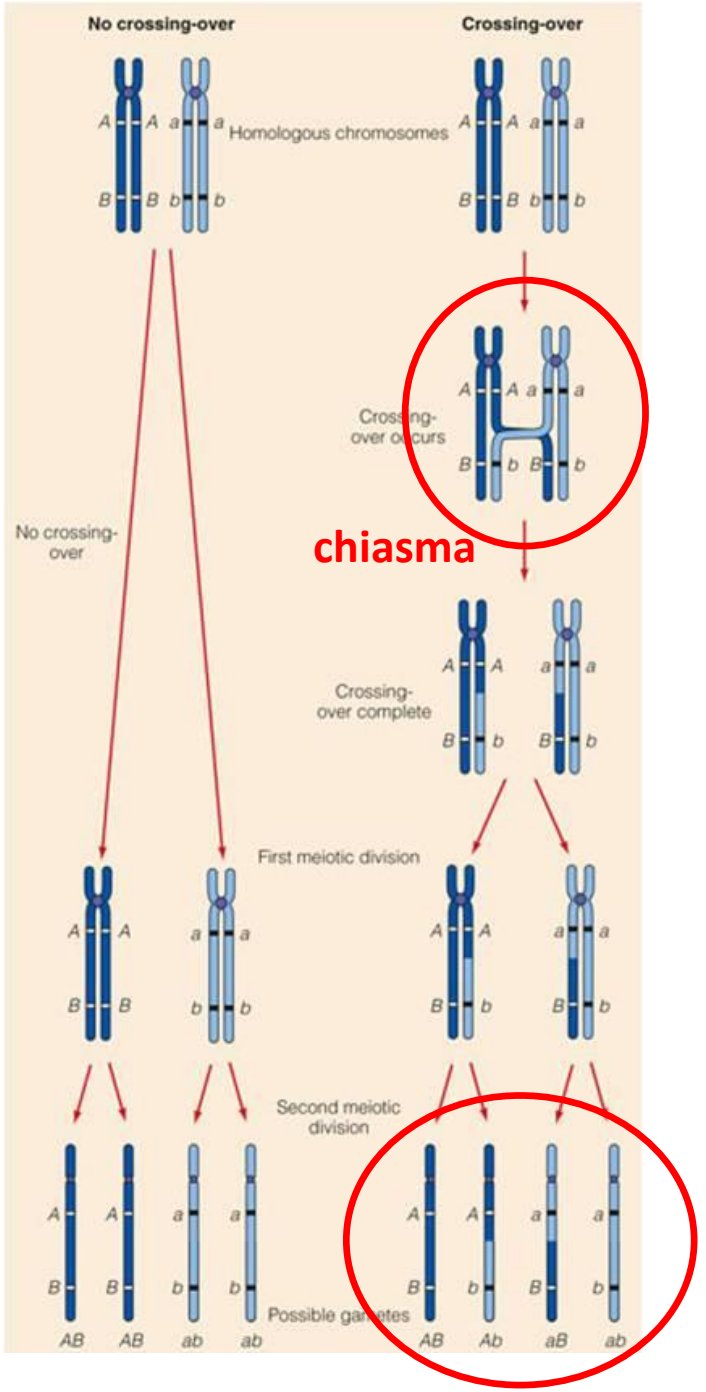
1. In meiosis I, members of **a pair of homologous chromosomes** physically associate

- **Crossing over occurs, which increases the genetic diversity in the gametes.**



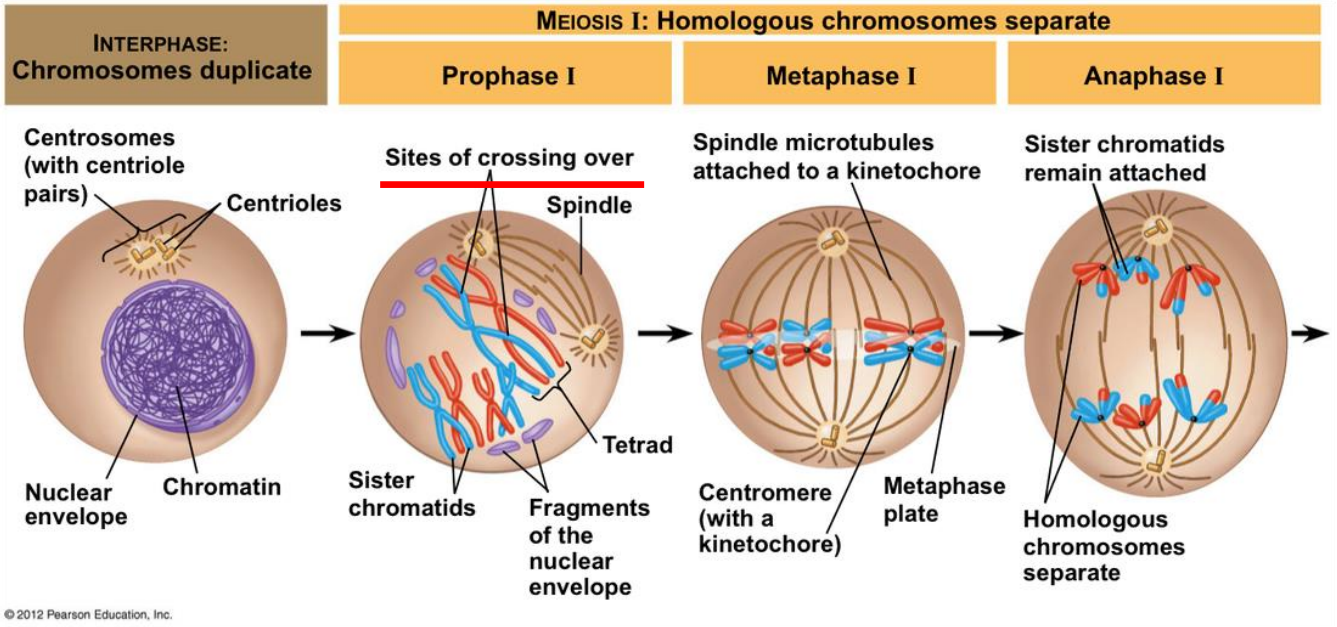
Prophase I. Crossing over

- 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



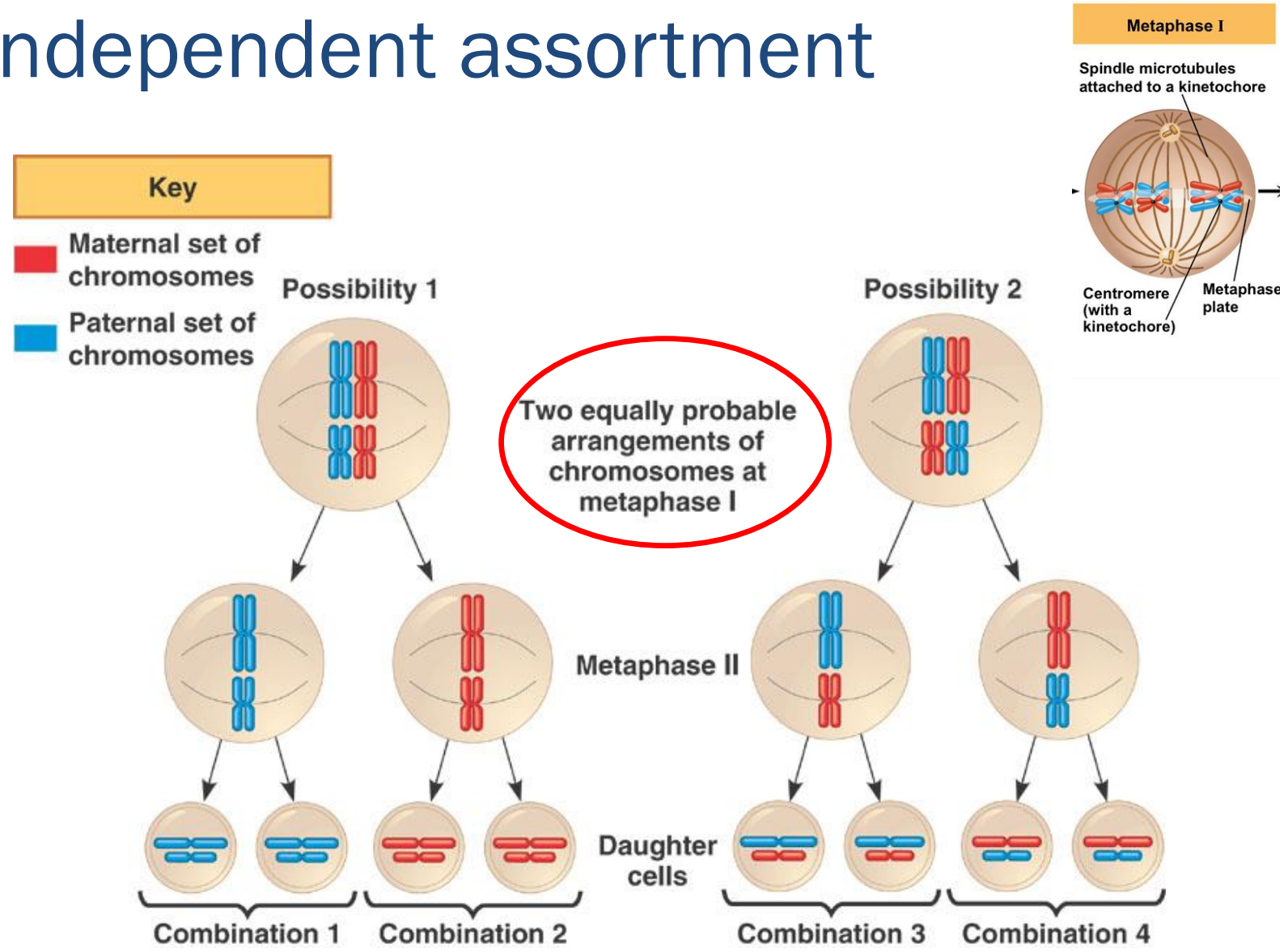
Meiosis I. Independent assortment

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



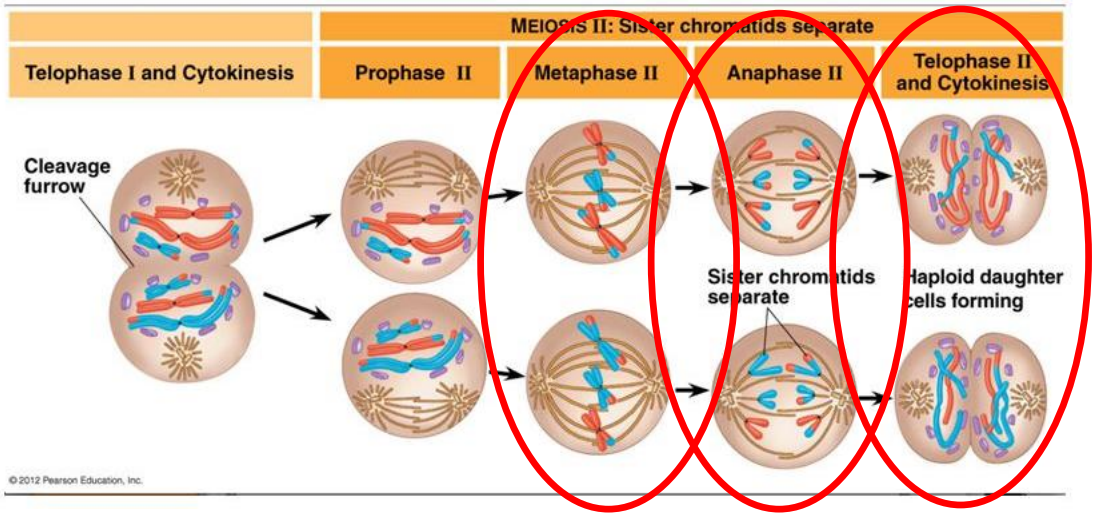
1. Homologous chromosomes line up **randomly** at **metaphase**
2. Random combinations of maternal and paternal homologues separate at **anaphase**

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

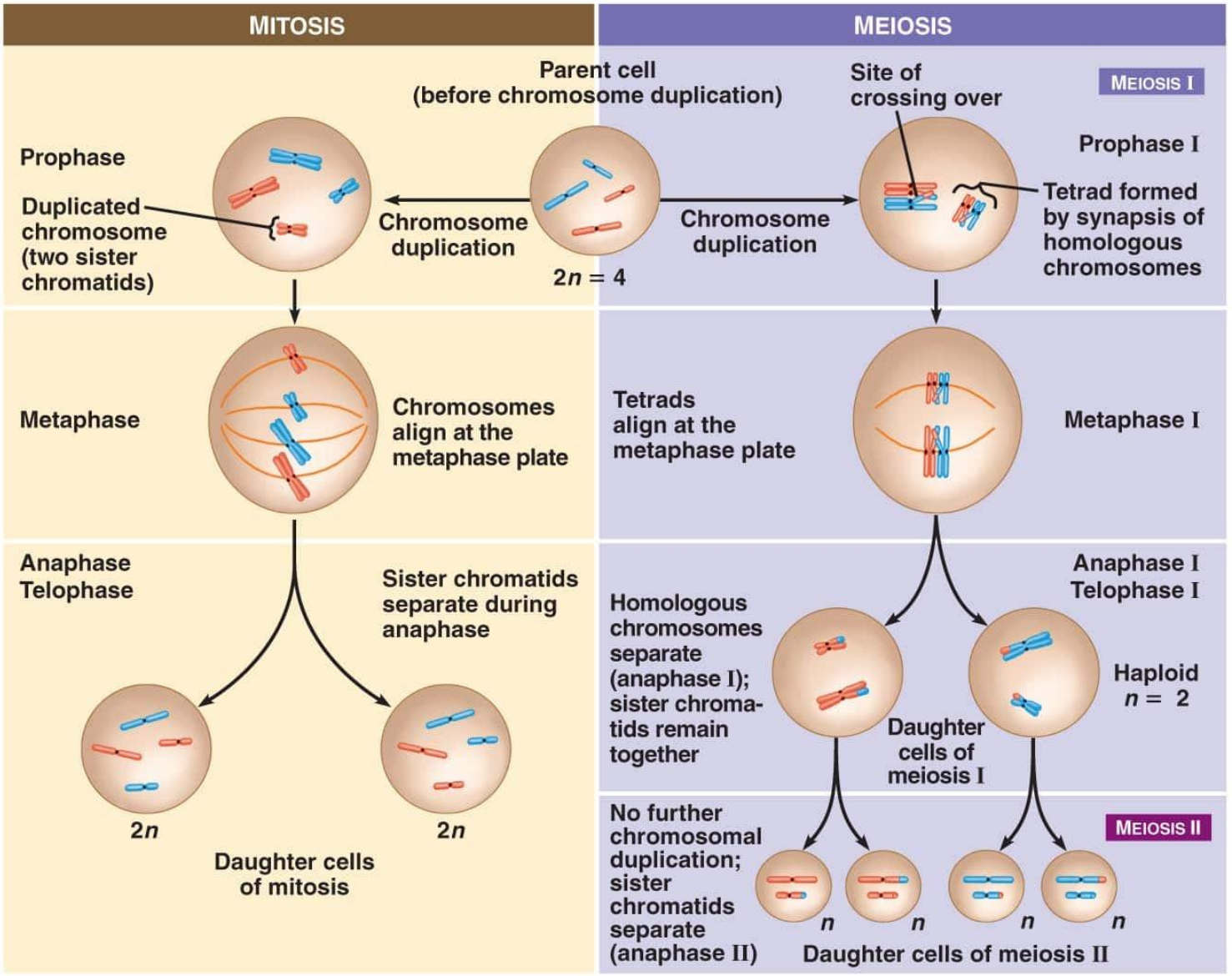
Anaphase II

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

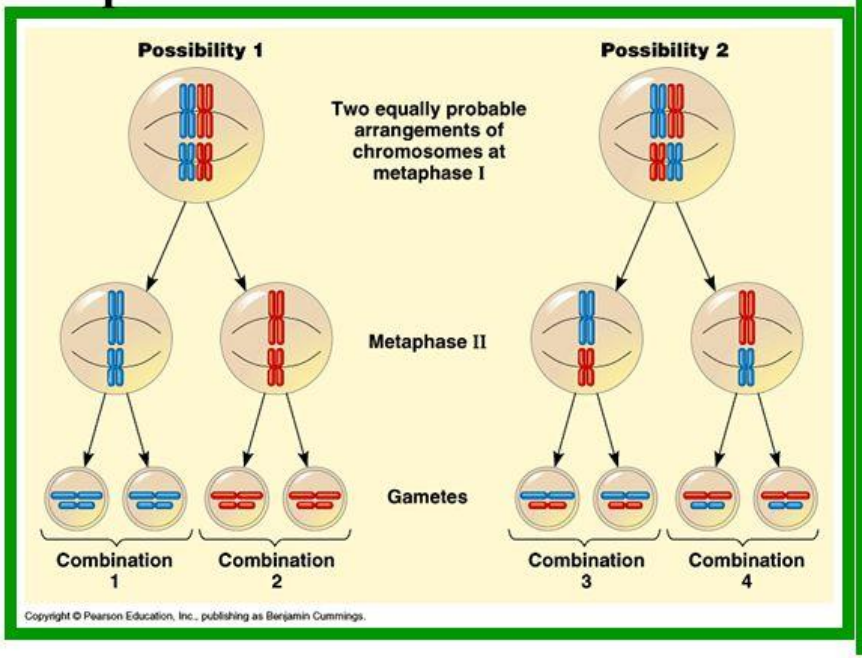
Meiosis

How do we account for genetic variation?

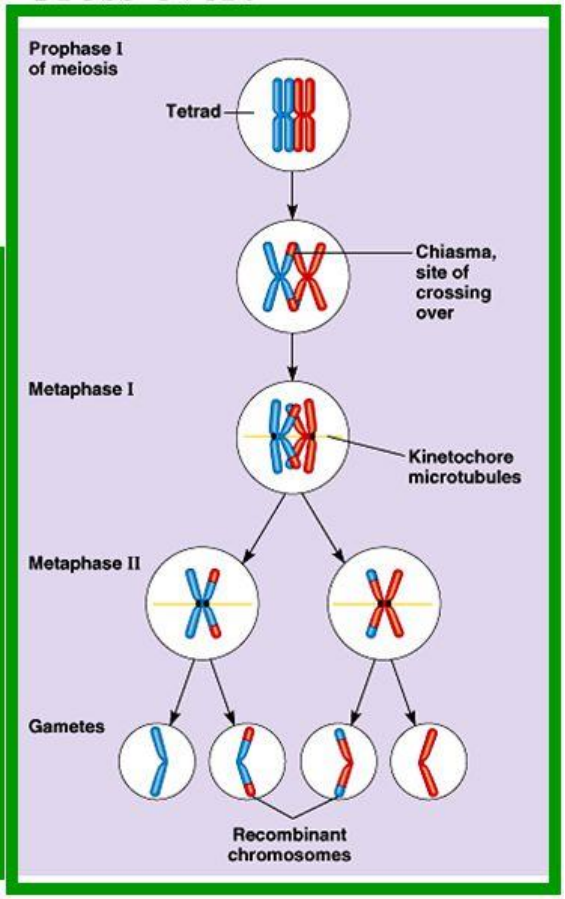
*Independent assortment

*Crossing over

Independent Assortment:

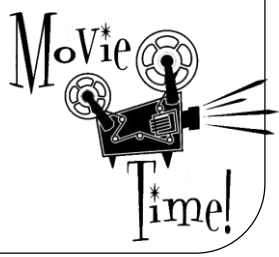


Cross over:



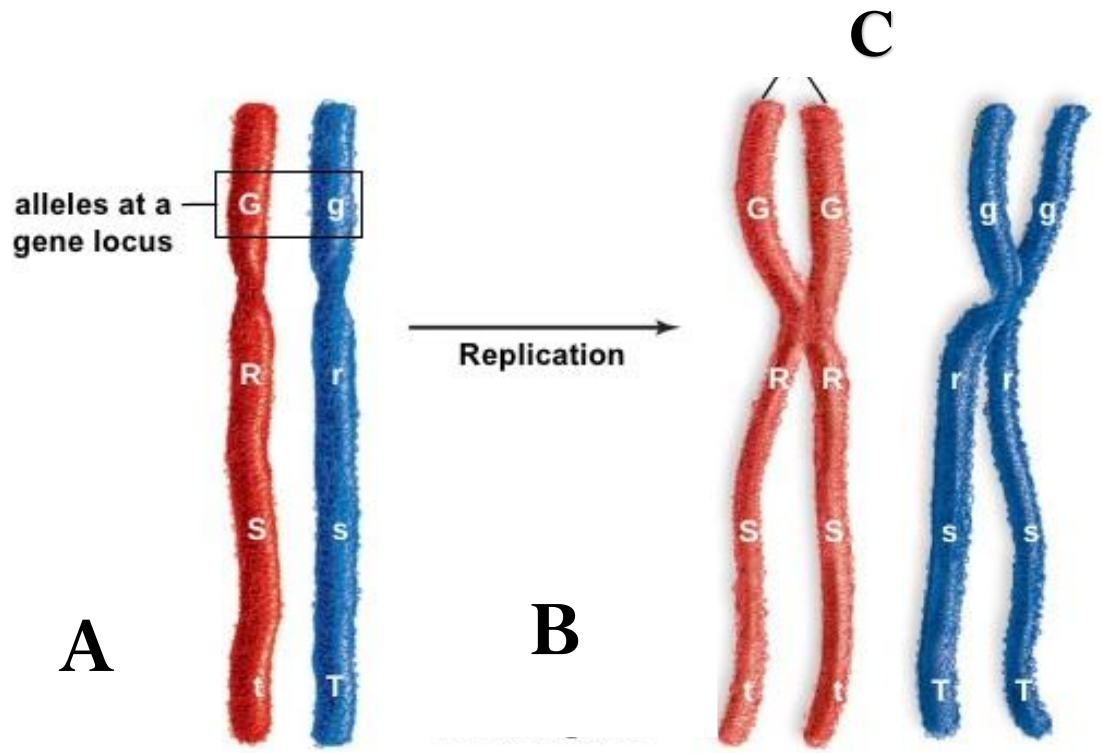
https://www.youtube.com/watch?v=-Zzp3mLIycM

4.20 min



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

Homologous Chromosomes



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