Enrichment course in Biology

2. Cell cycle and division

Dr. Yeung Man Nga, Mandy
Rm 4-23, School of Nursing
Tel:28192684
Email: mandyymn@hku.hk

Dr. Yick Pang Ching, Wilson
Rm L1-43, School of Biomedical Sciences,
Tel: 39179434
Email: ypching@hku.hk

Learning objectives

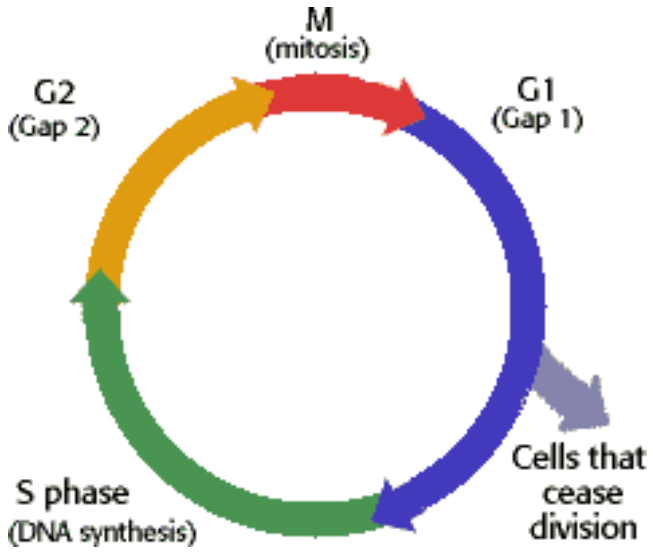
- What are the major stages of a cell cycle.
- What are the two specific types of cell division and their major difference.
- What are the problems of an abnormal cell cycle division.

Cell cycle

The cell cycle is an ordered set of events, culminating in cell growth and division into two daughter cells.

Stages of cell cycle

1. **G_1 phase**
   : cell **g**rowth
   : preparation for DNA replication
2. **S phase**
   : **s**ynthesis of DNA (replication)
3. **G_2 phase**
   : preparation for division
4. **M (mitosis) phase**
   : nuclear and cell division



** Non-dividing cells are not in cell cycle (e.g. cardiac muscle cells, neurons…)*

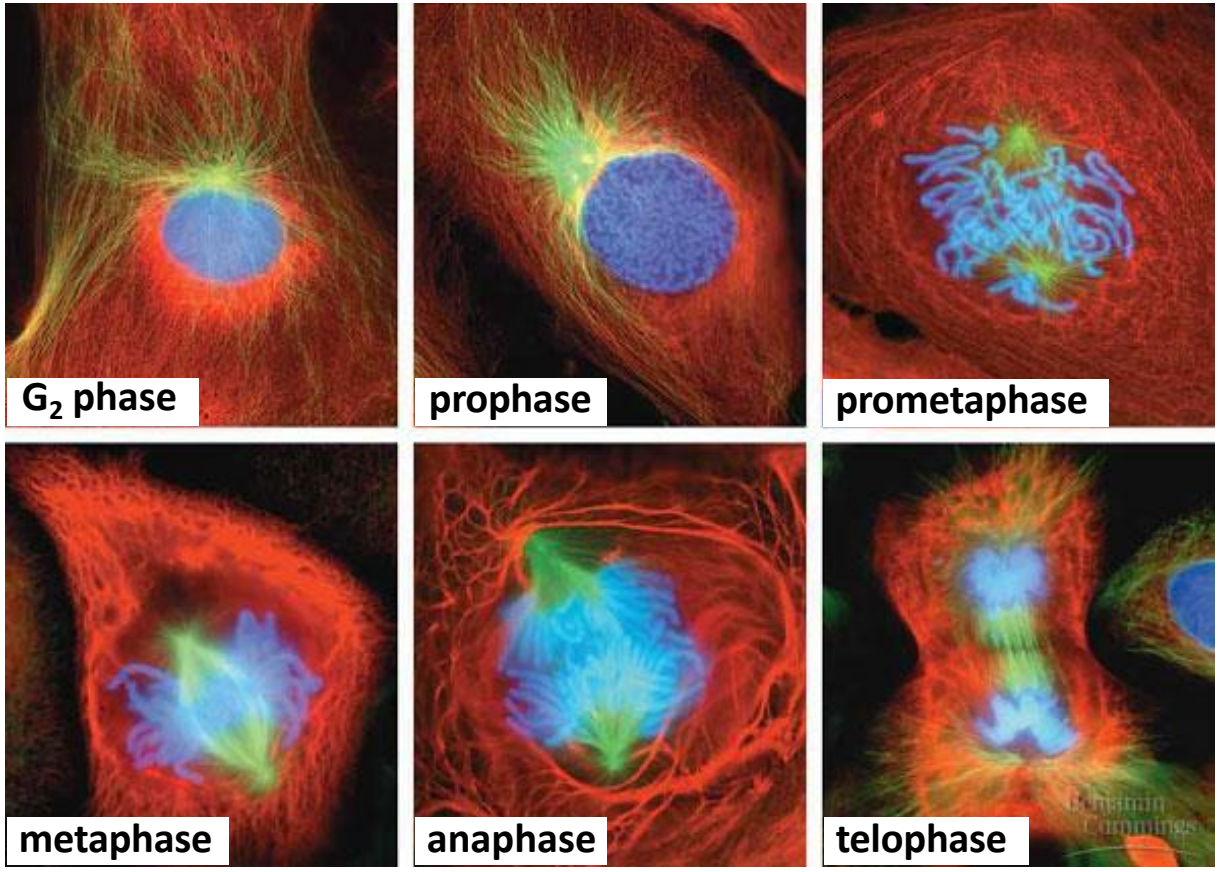
**G1 to G2 phases are also called Interphase*

Mitosis

Mitosis = nuclear division

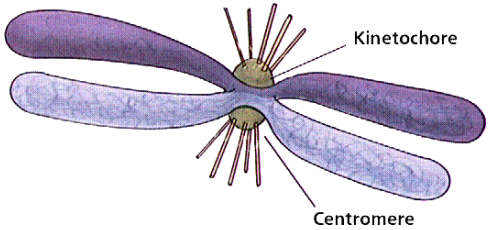
Mitosis is divided into 4 stages

1. Prophase
2. Metaphase
3. Anaphase
4. Telophase

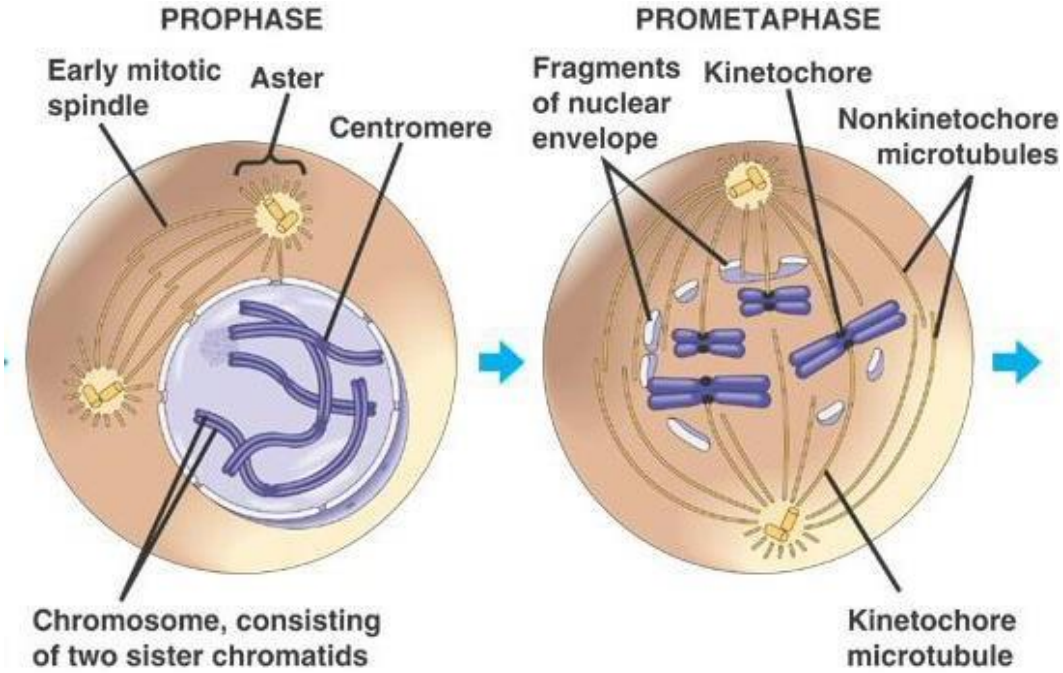


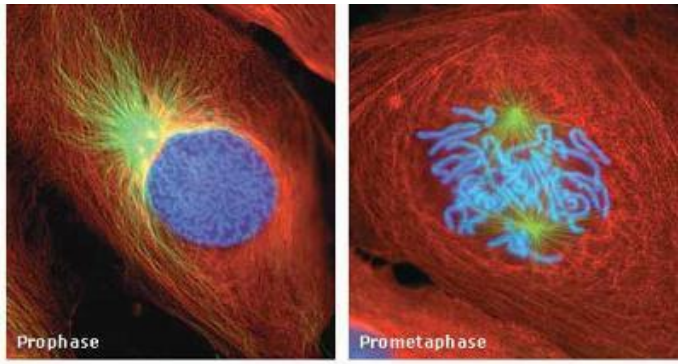
Mitosis is followed by cell division (cytokinesis)

Mitosis

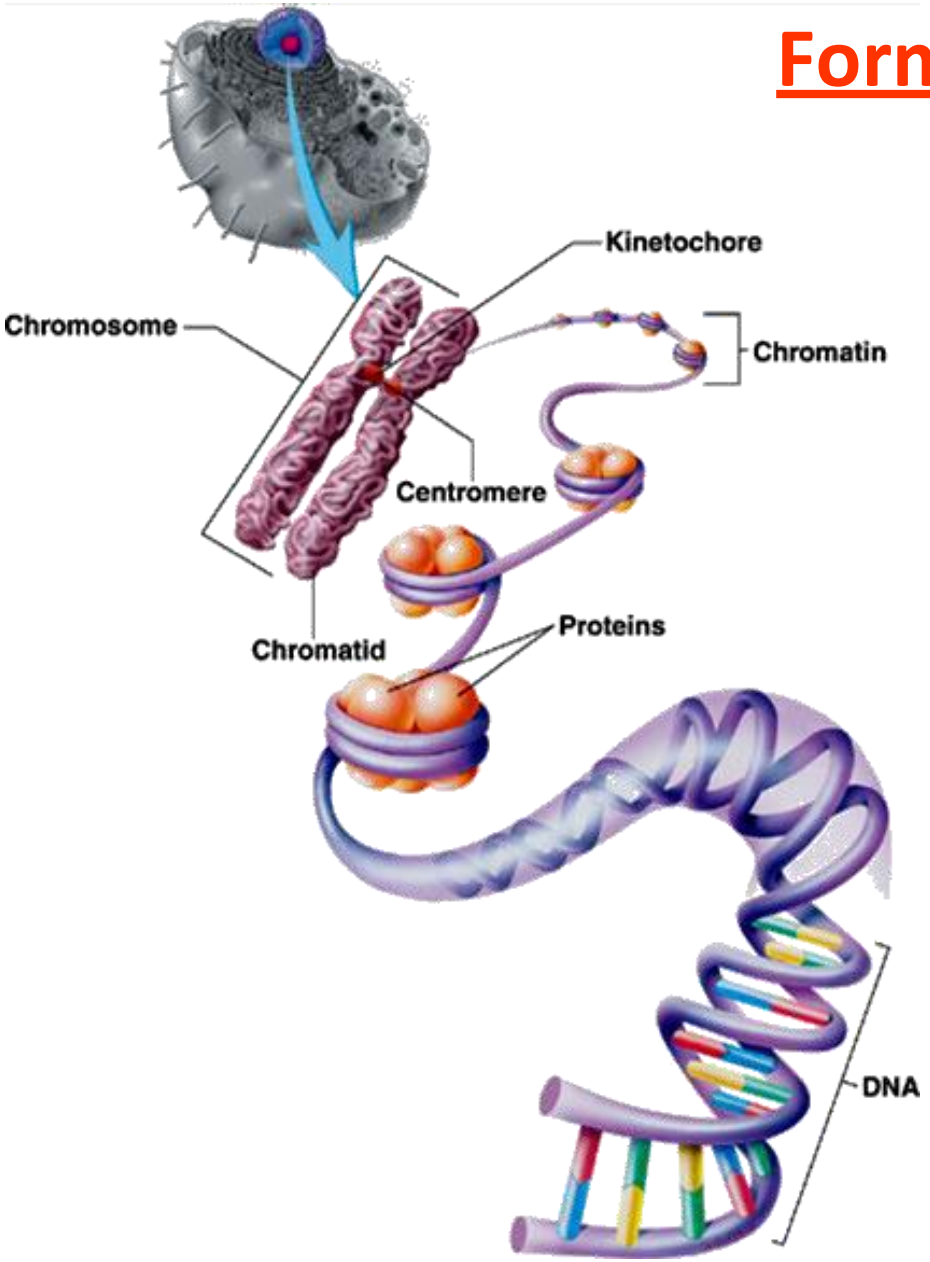


- **Prophase**
  - Chromatin condensed into chromosomes (sister chromatids)
  - Centrosome move to opposite poles of the cells
  - Spindle fibers extend from centrosome to join the sister chromatids at centromere
  - Nuclear envelope disappears



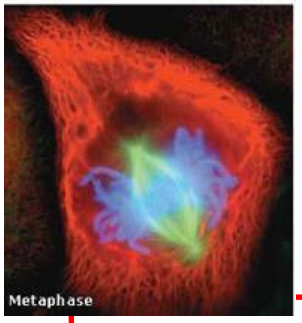


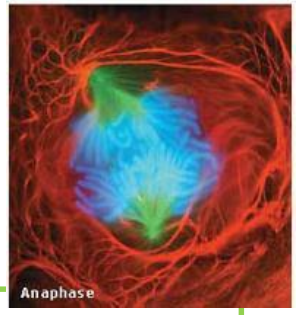
Formation of sister chromatids



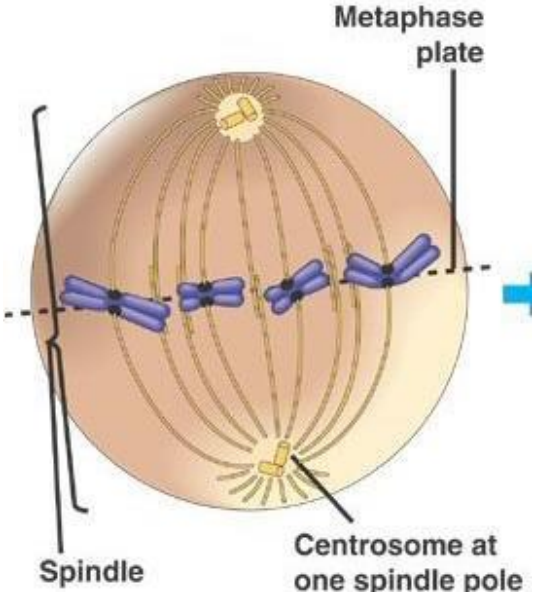
- **Chromatin**: DNA winds on nuclear protein called histones
- Chromatin bends and twists together to form **chromosome** (condensed)
- When cells divide, DNA is duplicated, the 2 identical chromatins condense to form 2 chromosomes. These 2 identical chromosomes are linked together through **centromere** (**sister chromatids**)

Mitosis

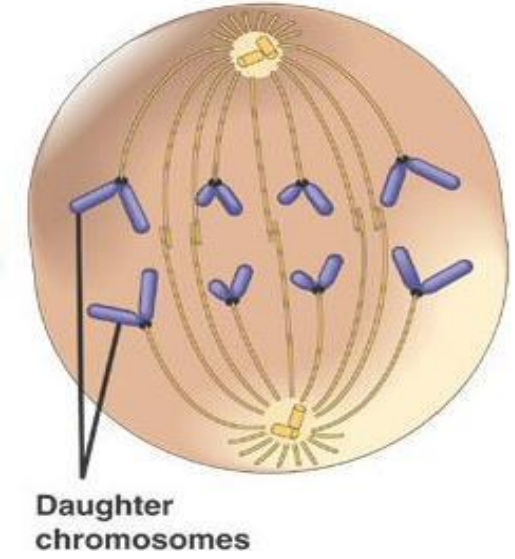




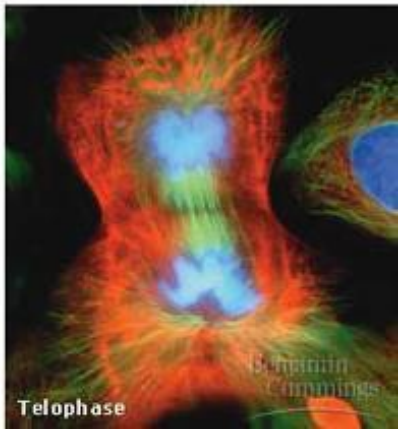
- **Metaphase**
  - Sister chromatids aligned at metaphase plate



- **Anaphase**
  - Sister chromatids separated and pulled to opposite poles by spindle fiber

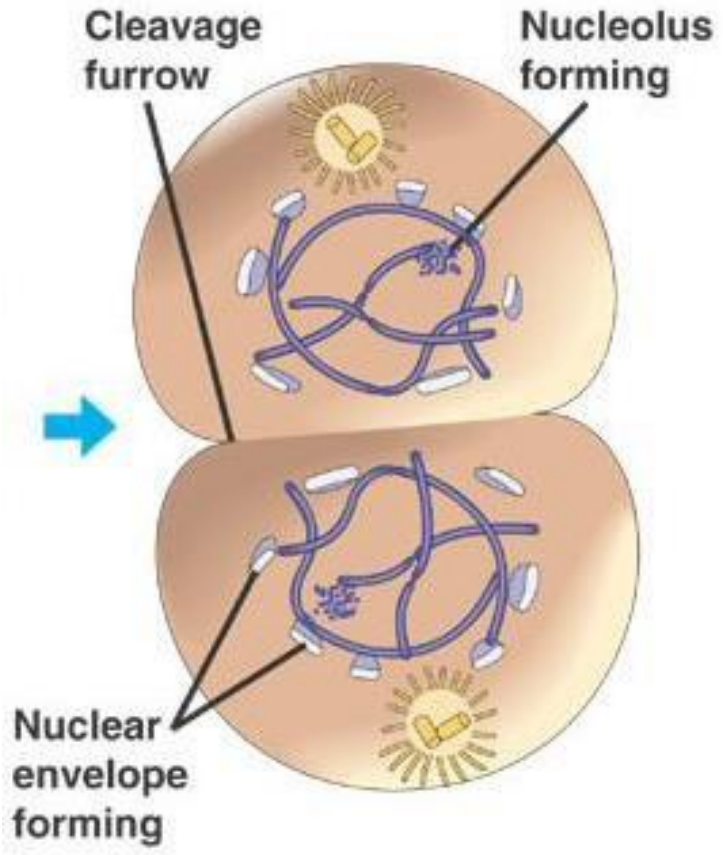


Mitosis



- **Telophase**
  - Chromosomes separate from spindle fibres
  - Chromosomes gradually unwind into chromatin
  - Nuclear envelope reforms
  - Nucleoli reform

- **Cytokinesis**
  - Cytoplasm constricts along the plane of metaphase plate to form a cleavage furrow
  - Separation of the dividing cell into 2 daughter cells



Cell cycle is a highly regulated process

Different proteins are involved in regulating the progression of cell cycle from one phase to another phase (i.e. from G_1 to S, from G_2 to M)

These proteins are: **cyclin and cyclin-dependent kinase (CDK)**

Checkpoint proteins prevent progression of cell cycle when something goes wrong (e.g. p53 and p27 prevents progression if there is DNA damage)

Mutation in proteins that regulate cell cycles could result in **cancer**

Meiosis

Another type of nuclear division that occurs in the gonad only

Gonad = ovaries in female, testis in male

Function of meiosis: to produce gametes for reproduction

Female gamete = egg

Male gamete = sperm

Fusion of gamete = fertilization

During meiosis, the nucleus divide for 2 times resulting in 4 daughter cells

1st division = meiosis I (prophase I, metaphase I, anaphase I, telophase I)

2nd division = meiosis II (prophase II, metaphase II, anaphase II, telophase II)

Meiosis I

Before the start of meiosis 1, DNA is duplicated like mitosis

Prophase I

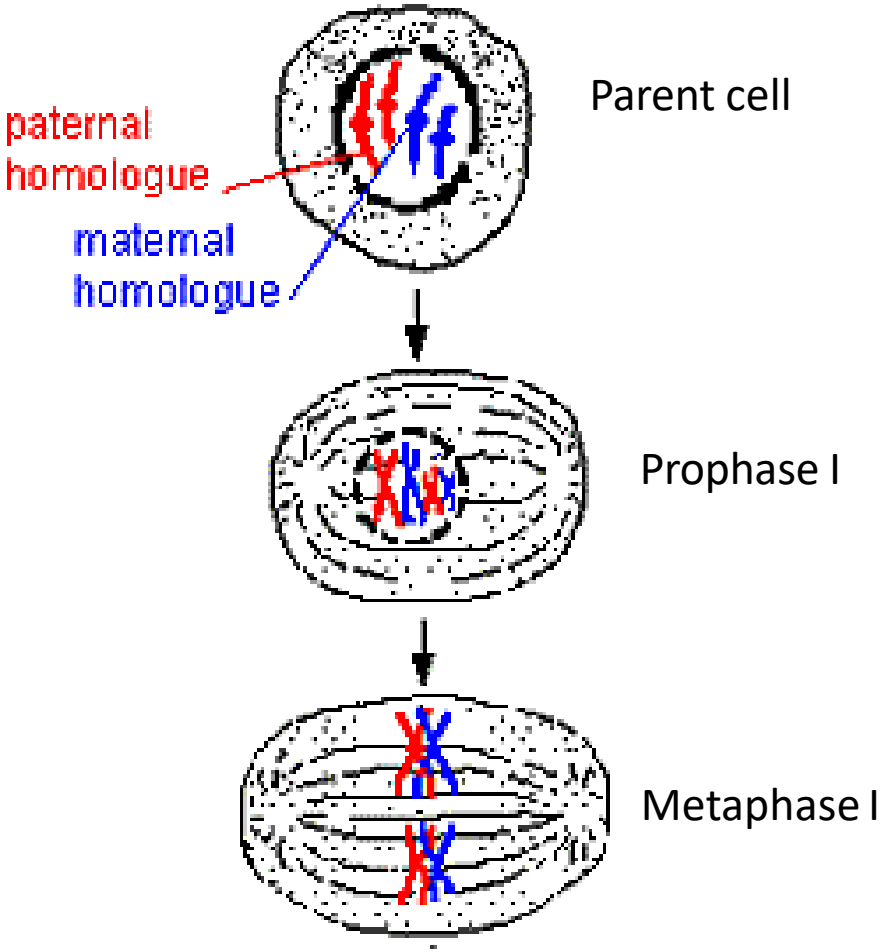
: paring up of homologous chromosome

: crossing over occurs in late prophase I between homologous chromosomes

Metaphase II

: homologous chromosome paired up and aligned at the metaphase plate

2n = diploid cell (2 sets of chromosome)



http://www.accessexcellence.org/RC/VL/GG/meiosis.php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X
Y

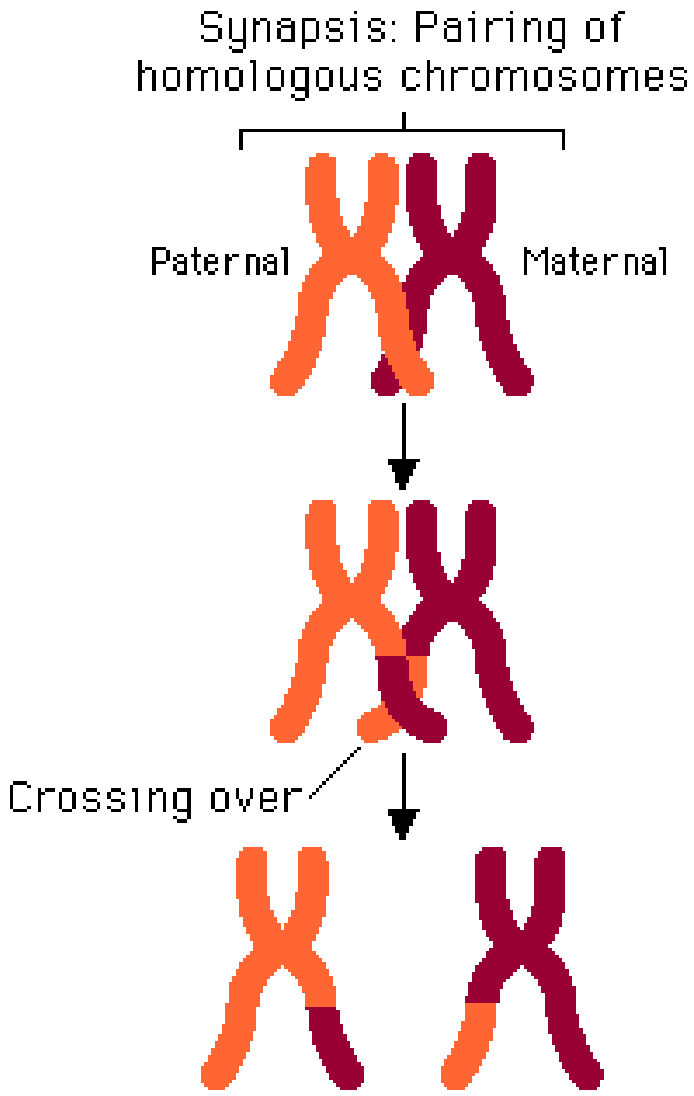
Crossing over

Crossing over

= exchange on DNA between the 2 homologous chromosome

** This process is random and non-predictable*

Result: increase genetic variation in gametes



http://www.phschool.com/science/biology_place/labbench/lab3/crossovr.html

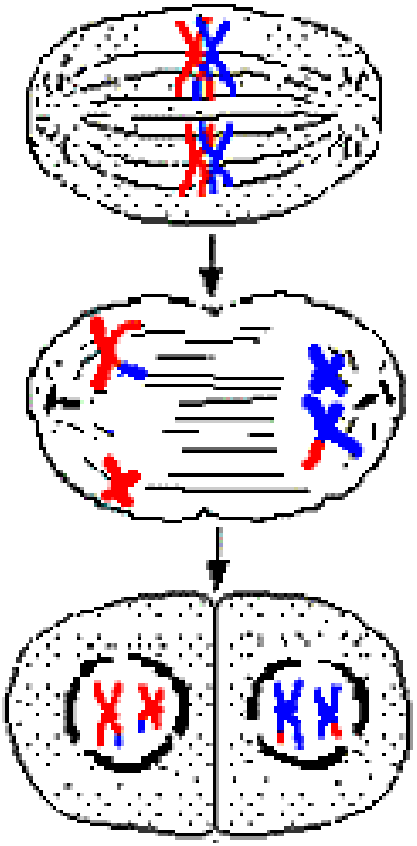
Meiosis I

Anaphase I

: separation of homologous chromosome

Telophase I

: 2 daughter cells are formed



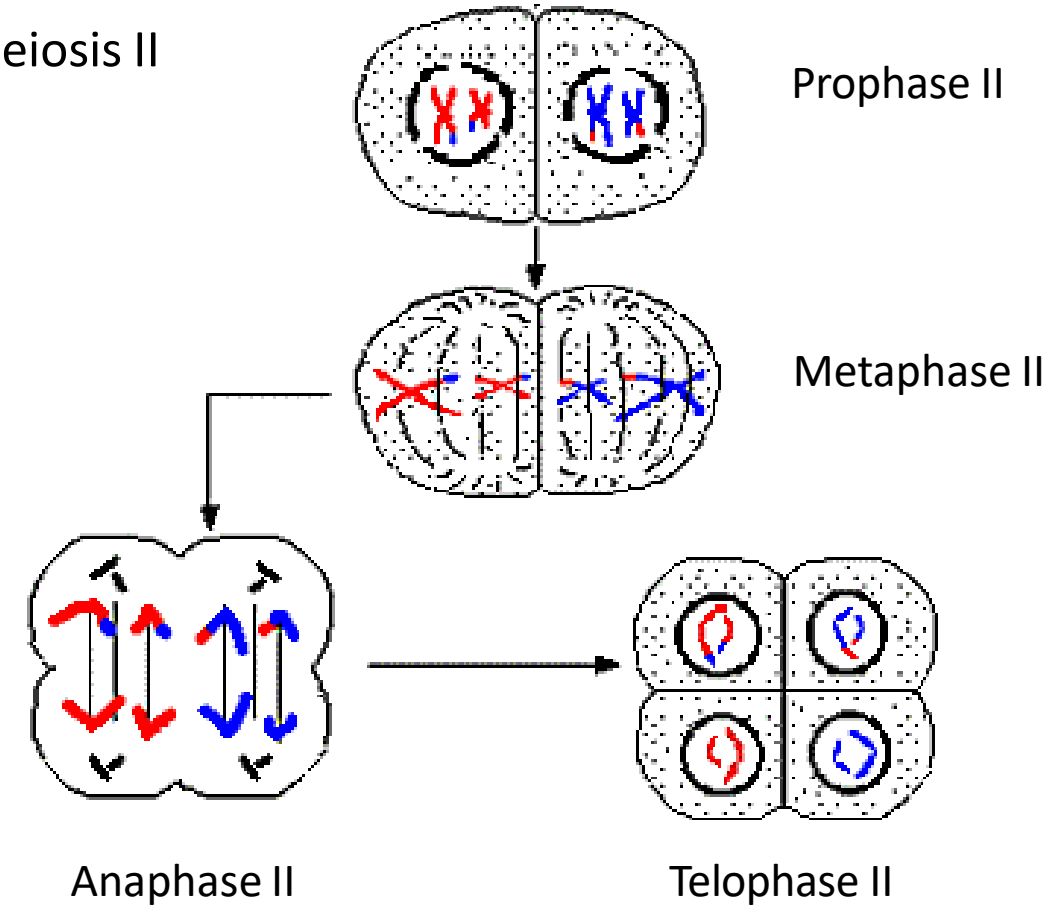
http://www.accessexcellence.org/RC/VL/GG/meiosis.php

Meiosis II

No DNA duplication preceding meiosis II

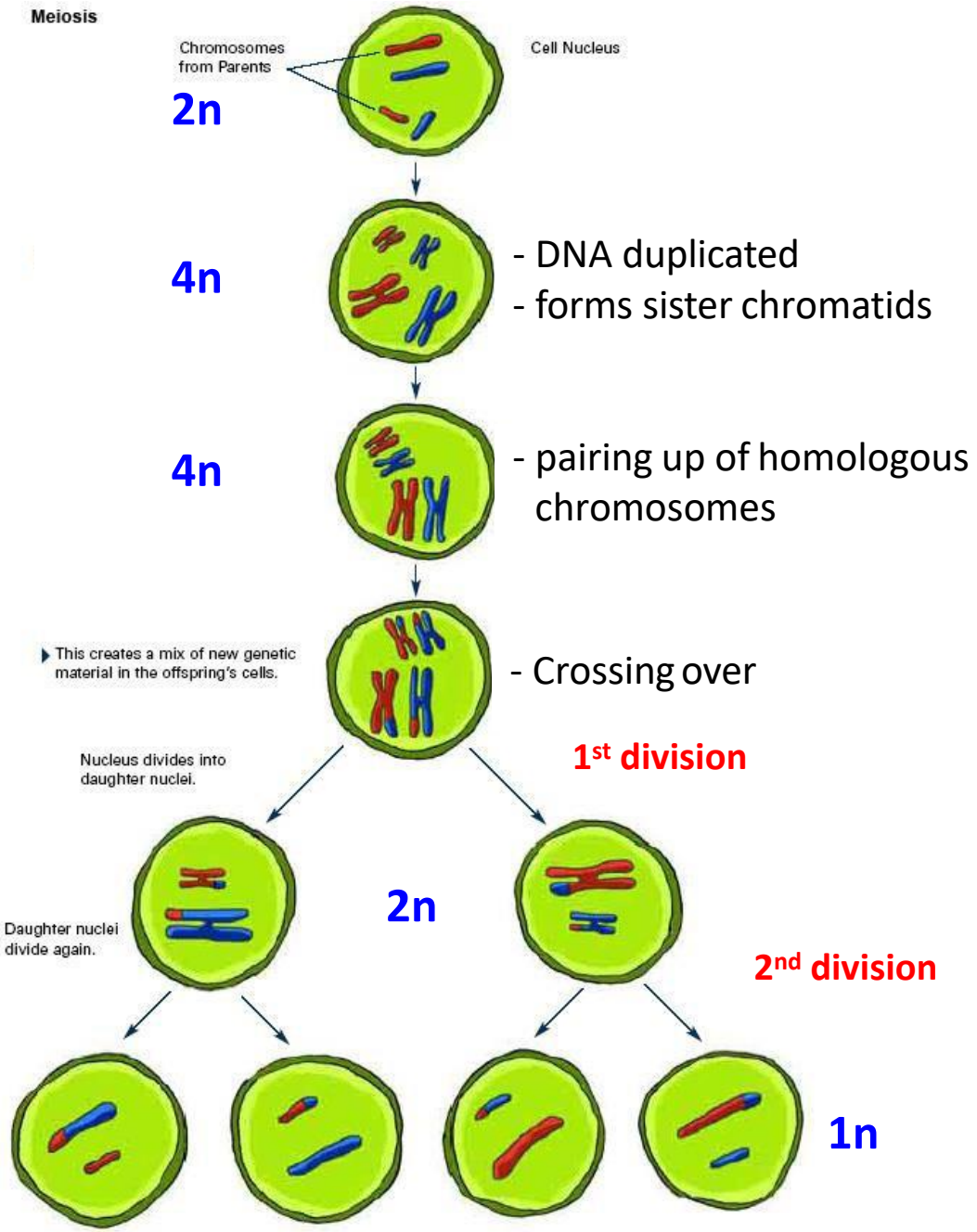
Meiosis II is similar to mitosis

At the end of meiosis, 4 daughter cells are formed. Each daughter cell contains only 1 set of chromosome (1n), therefore they are called **haploid** cells.



http://www.accessexcellence.org/RC/VL/GG/meiosis.php

Meiosis



http://www.wereyouwondering.com/what-is-the-difference-between-mitosis-and-meiosis/

Chromosomal abnormalities

A. Change in number of chromosomes

1. **Euploidy**
   - change in no. of sets of chromosome
   - e.g. triploid (3n) – 3 sets of chromosomes
2. **Aneuploidy**
   - no. of a particular chromosome is not 2
   - e.g. trisomy 21 (Down syndrome)

Arise from **problem during separation of chromosome** during cell division

B. Structural changes (chromosomal rearrangement)

1. **Duplication**
2. **Deletion**
3. **Inversion**
4. **Translocation**

Arise from **problem during crossing-over**

Outcome:

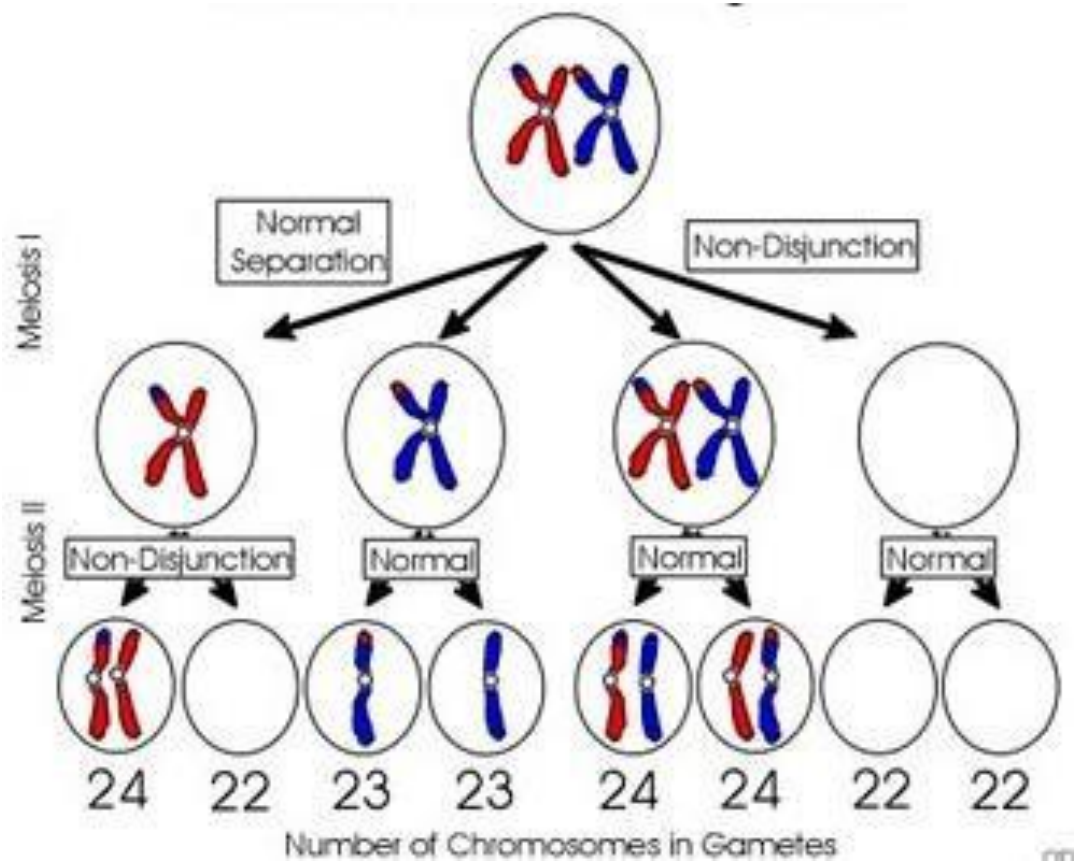
1. spontaneous abortion (most of them)
2. birth defects

How dose trisomy arise?

Non-disjunction of chromsome during 1st or 2nd meiotic division

1. failure of separation of homologous chromosome (1st division)

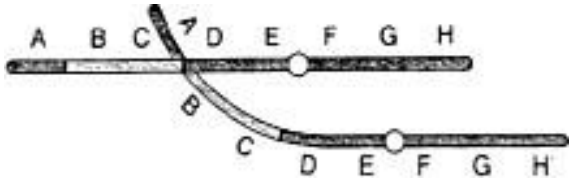
2. failure of separation of sister chromatids (2nd division)



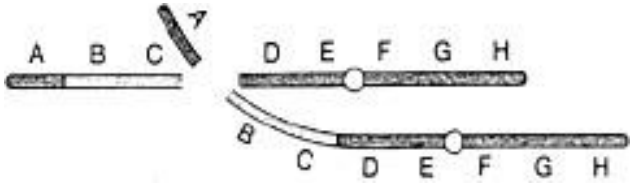
Duplication and deletion

How may duplication and deletion arise?

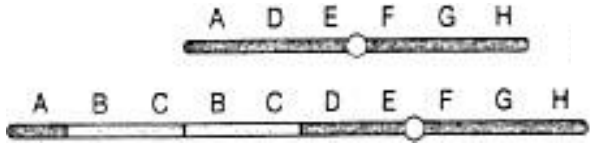
Step1:
Homologous chromosomes overlap at wrong position



Step2:
Simultaneous strand break at overlapping site



Step 3:
Reunion of chromosome segments



Deletion

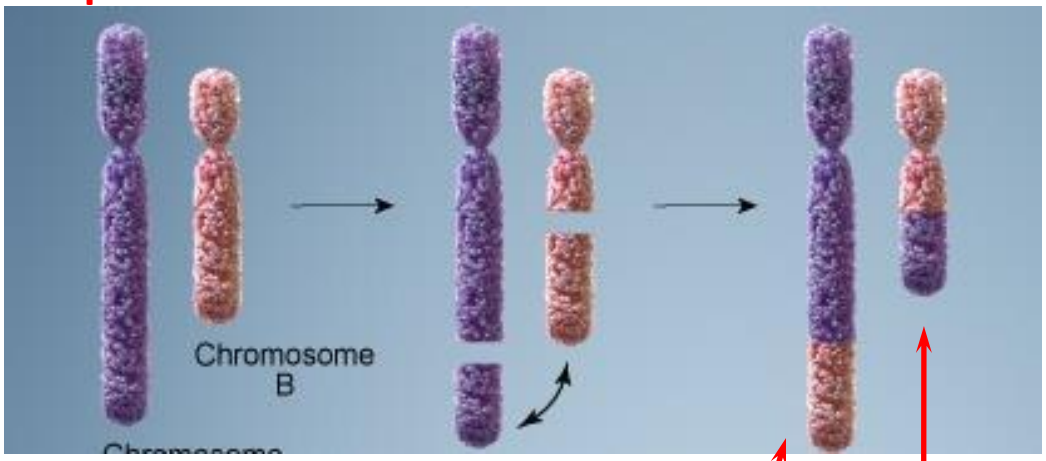
Duplication

Translocation

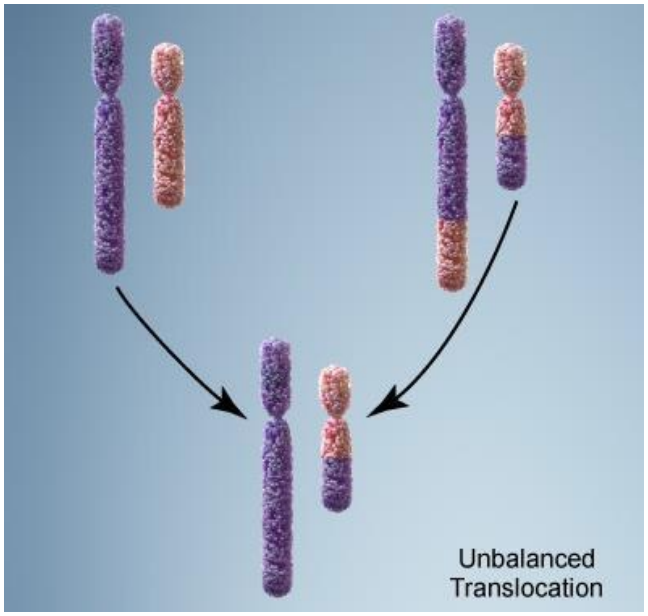
Interstitial translocation (1-way movement only)
- part of the chromosome is inserted into the middle /the end of another chromosome

Reciprocal translocation (2-way exchange)
- exchange of part of chromosome between 2 different chromosomes

Reciprocal translocation



Balanced translocation if both goes into the same gamete



If either one gets into a gamete → unbalanced translocation

Suggested reading

Maartini, F. H., Nath, J. L., & Bartholomew, E.F. (2012). *Fundamentals of anatomy and physiology.* (9th Ed.). San Francisco : Pearson/Benjamin Cummings (Chapter 3, p96-103)

Fox, S. I. (2011). *Human Physiology.* (12th Ed.) New York : McGraw-Hill (Chapter 3.5)