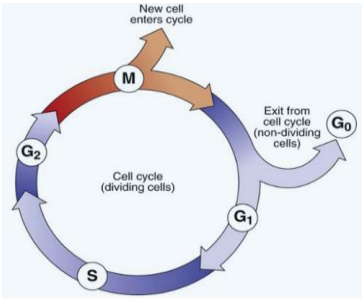
Lecture-2

Cell Cycle and Cell Division

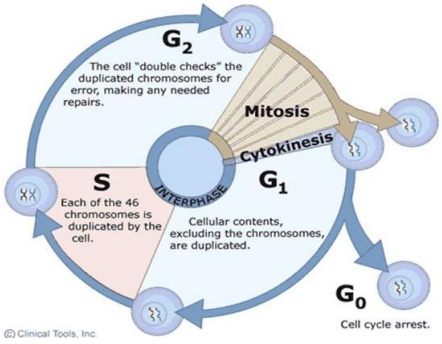
Cell Cycle

- The period between successive mitoses is known as **interphase** of cell cycle .
- In rapidly dividing cells this lasts for between 16 and 24 hours.
- Interphase commences with the G_1 (G = gap) phase during which the chromosomes become thin and extended.
- Cells that have stopped dividing, such as neurons, usually arrest in this phase and are said to have entered a noncyclic stage known as G_0.
- Interphase is completed by a relatively short G_2 phase during which the chromosomes begin to condense in preparation for the next mitotic division.



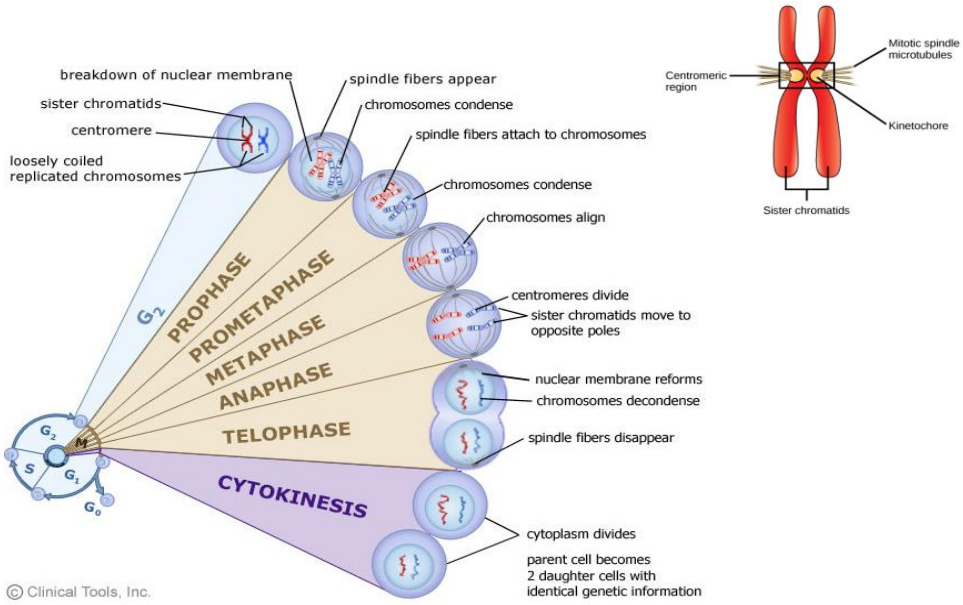
Cell Cycle

Phase	Feature
G0	Cell left the cycle and stopped dividing. Senescent (aged) cells or non-dividing cells (neurons)
G1	Cells increase in size in Gap 1. G1 check point ensures that everything is ready for S phase or DNA synthesis.
S	DNA replication
G2	Cell continues to grow. G2 check point ensures that everything is ready to enter M phase.
M	Cell growth stops. Call divides into two daughter cells.



Mitosis

- Mitosis is a form of eukaryotic cell division that produces two daughter cells with the same genetic component as the parent cell.
- Mitosis takes place in somatic cells and during the early cell divisions in gamete formation.
- Mitosis results in each daughter cell having diploid chromosomes (2n = 46).
- Each daughter cell receives a copy of every chromosome.
- In actively dividing animal cells, the whole process takes about one hour.
- Mitosis is divided into five stages:
  - Prophase
  - Prometaphase
  - Metaphase
  - Anaphase
  - Telophase



Mitosis stages

Phase	Feature
Prophase	Nucleus disappears, spindle fibers form, DNA condenses into chromosomes (sister chromatids).
Prometa-phase	Kinetochores appear at centromeres. Spindle fibers attach to kinetochores, centrosomes move towards opposite poles.
Metaphase	Spindle fully developed, centrosomes at opposite poles, Chromosomes aligned along the equator of the cell.
Anaphase	Sister chromatids are separated and pulled towards opposite poles of the cell by mitotic spindle.
Telophase	Chromosomes arrive at opposite poles and de-condense, spindle fibers disappear, nuclear membrane reappears.
Cytokinesis	Cytoplasm divides, splitting of the cell membrane, formation of 2 daughter cells with identical genetic material.

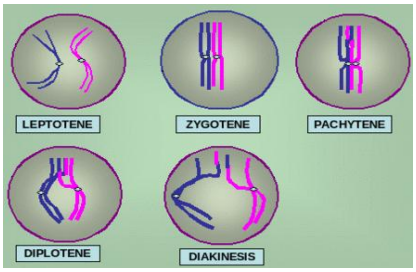
Meiosis

- During meiosis the diploid count is halved so that each mature gamete receives a haploid complement of chromosomes (n = 23 in humans).
- Meiosis occurs only at the final division of gamete maturation.
- Meiosis produces **haploid** sex cells or gametes (which contain a single copy of each chromosome) from **diploid** cells (which contain two copies of each chromosome).
- Meiosis involves one DNA replication followed by two successive cell divisions (Meiosis I and Meiosis II).
- Meiosis-I separates the pairs of homologous chromosomes.
- Meiosis-1 is also known as the **reduction division**, because chromosome number is halved by this process.
- Meiosis-II separates each chromosome into two chromatids.

Meiosis-I

Phase	Feature
Prophase-1	Homologous chromosomes pair and exchange DNA to form recombinant chromosomes. It is divided into 5 phases.
Metaphase-1	Nuclear membrane disappears. Homologous pairs of chromosomes (**bivalents**) randomly arranged as a double row along the metaphase plate.
Anaphase-1	Homologous chromosomes are separated and move to the opposite poles of the cell.
Telophase-1	The chromosomes become diffuse and the nuclear membrane reforms.
Cytokinesis	Cellular division to form two new cells. The original diploid cell had two copies of each chromosome. The newly formed haploid cells have one copy of each chromosome.

Prophase-1



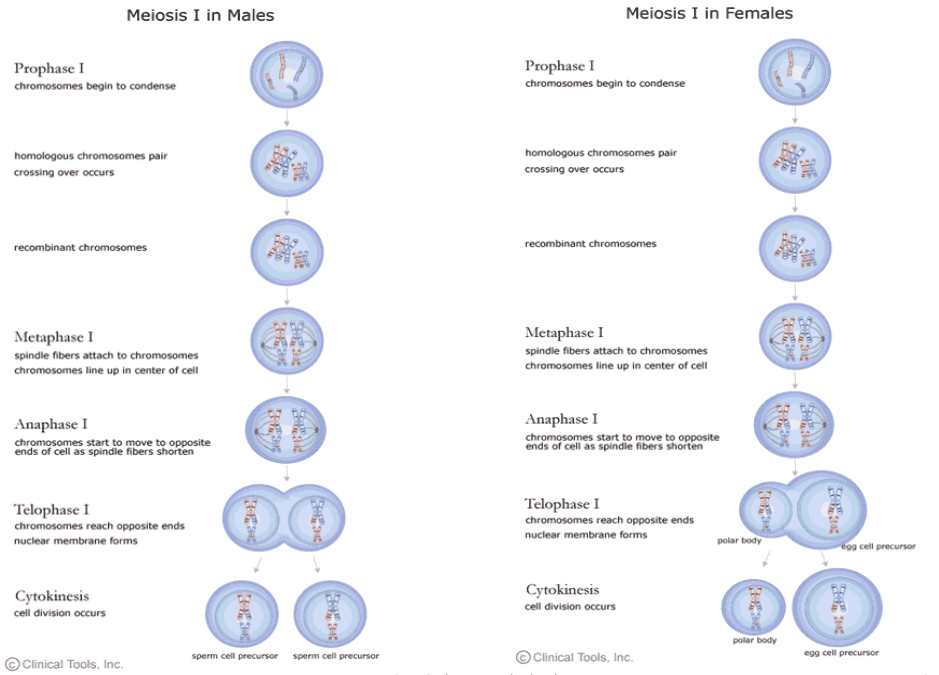
Leptotene- Chromosomes start to condense and become visible.

Zygotene- Homologous chromosomes become closely associated (synapsis) to form pairs of chromosomes (bivalents) consisting of 4 chromatids (tetrads).

Pachytene- Crossing over between pairs of homologous chromosomes to form chiasmata. Exchange of DNA between chromatids.

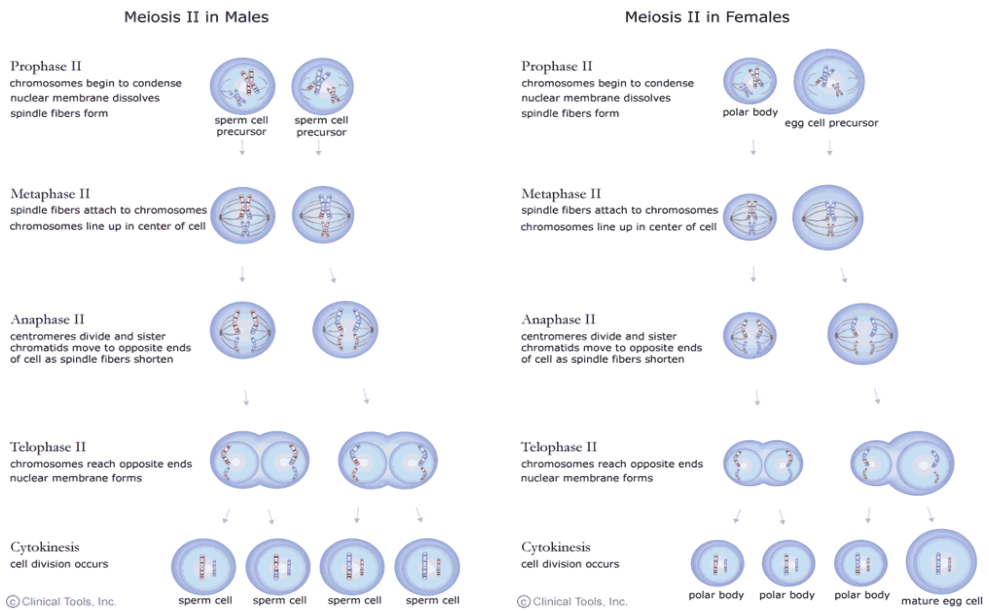
Diplotene- Homologous chromosomes start to separate but remain attached at the points of crossing over (chiasmata).

Diakinesis- Separation of the homologous chromosome pairs proceeds as the chromosomes become maximally condensed.



Meiosis-II

Phase	Feature
Prophase-2	Chromosomes begin to condense, nuclear membrane dissolves, spindle fibers form.
Metaphase-2	Spindle fibers attach to chromosomes. Chromosomes align in center of cell.
Anaphase-2	Centromeres divide and sister chromatids move to opposite ends of cell. Spindle fibers shorten.
Telophase-2	Chromosomes reach opposite ends, and the nuclear membrane reforms.
Cytokinesis	Cellular division to form two new daughter cells (gametes).

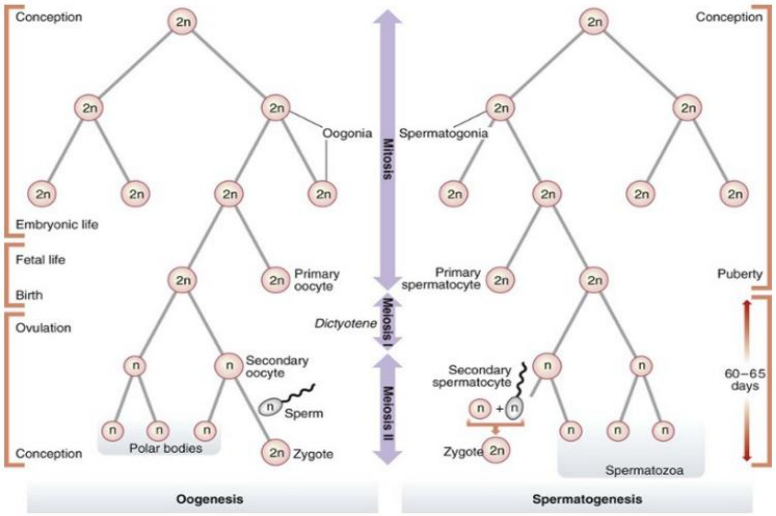


Meiosis (genetic diversity)

- Meiosis generates **genetic diversity** through:
- The exchange of genetic material between homologous chromosomes during Meiosis-I.
- The random alignment of maternal and paternal chromosomes in Meiosis-I.
- The random alignment of the sister chromatids at Meiosis-II.

Gametogenesis

	Males	Females
Commences	Puberty	Early embryonic life
Duration	60–65 days	10–50 years
Numbers of mitoses in gamete formation	30–500	20–30
Gamete production per meiosis	4 spermatids	1 ovum + 3 polar bodies
Gamete production	100–200 million per ejaculate	1 ovum per menstrual cycle



Oogenesis

- Mature ova develop from oogonia.
- Oogonia originate from germ cells by a process involving 20 to 30 mitotic divisions that occur during the first few months of embryonic life.
- By the completion of embryogenesis at 3 months of intrauterine life, the oogonia have begun to mature into primary oocytes.
- At birth all of the primary oocytes enter a phase of maturation arrest, known as **dictyotene**, in which they remain suspended until meiosis-I is completed at the time of ovulation, when a single secondary oocyte is formed.
- It is probable that very lengthy interval between the onset of meiosis and its eventual completion, up to 50 years later, accounts for increased incidence of chromosome abnormalities in the offspring of older mothers.
- The accumulating effects of ‘wear and tear’ on the primary oocyte during the dictyotene phase probably damage the cell’s spindle formation and repair mechanisms, thereby predisposing to **non-disjunction** (failure of homologous chromosomes to separate).

Spermatogenesis

- Spermatogenesis is a rapid process with average duration of 60 - 65 days.
- At puberty **spermatogonia**, which already have undergone approximately 30 mitotic divisions, begin to mature into **primary spermatocytes** which enter meiosis-I and emerge as haploid **secondary spermatocytes**.
- They undergo the second meiotic division to form **spermatids**, which develop into **mature spermatozoa**, of which 100 to 200 million are present in each ejaculate.
- Spermatogenesis is a continuous process involving many mitotic divisions (20 to 25 per annum), so that spermatozoa produced by 50 year or older man could well have undergone several hundred mitotic divisions.
- The observed paternal age effect for new dominant mutations is consistent with the concept that many mutations arise as a consequence of DNA copy errors during mitosis.