Meiosis
Dr. Shayma`a J. Ahmed

First Meiotic Division

- In Prophase I, the matching chromosomes from your mother and father pair up.
- While paired up, maternal and paternal chromosomes can swap matching sections. This process, called crossing over, increases genetic diversity.

Second Meiotic Division

The four daughter cells have half as many chromosomes as the parent cell and are called haploid.
Objectives:

- Define the Meiosis.
- List the Phases of Meiosis.
- Describe the Stages of Meiosis.
- Determine the features of Meiosis.
- Compare between the mitosis & meiosis.
- Describe the **Meiosis Sex Differences**.
- Nice to know the clinical features of the genetic diseases in this lecture.
Meiosis: making egg and sperm cells

- A process called ‘meiosis’ creates new reproductive cells with half as many chromosomes as the original cell. Without meiosis, joining of the egg and sperm at fertilization would produce offspring with twice the original number of chromosomes as it`s parents.
- Starts with one reproductive cell (containing 46 chromosomes) that replicates its DNA only once but divides twice to produce four new cells, each having only 23 chromosomes.
- It consists of two nuclear divisions- Meiosis-I & Meiosis-II.
Meiosis-I:

- **Interphase**: Before meiosis begins, genetic material is duplicated.

- **Meiosis-I** has two main purposes:
  1. It is the reduction division, so it reduces the number of chromosomes in half, making the daughter cells haploid (when the parent cell was diploid).
  2. It is during meiosis I that most of the genetic recombination occurs.

- **Phases**:

  Keep in mind that before meiosis begins at all, the DNA undergoes replication, just like it did before mitosis started. So, when you first see chromosomes in meiosis I, they have sister chromatids, just like in mitosis. It is just that in meiosis-I, we will be talking about tetrads becoming visible, lining up, separating, and decondensing (rather than chromosomes, like in mitosis). Finally, cytokinesis occurs, too, any time after the tetrads have moved out of the equator (just like in mitosis).
Prophase I:

- Prophase I is further divided into five stages (phases):
  1- Leptotene:
    - leptotene phase, leptonema; Greek, leptotene = "thin threads"
    - the duplicated paired chromosome homologs condense.

2-Zygotene:

- zygotene phase, zygonema, Greek, zygotene = "paired threads"
- homologous chromosomes become closely associated (synapsis) to form pairs of chromosomes consisting of four chromatids (tetrads).
- the synaptonemal complex begins to form between the two sets of sister chromatids in each bivalent (the duplicated chromosome paired with its homologous duplicated chromosome).
3-Pachytene:
- pachytene phase, pachynema; Greek, pachytene = "thick threads"
- crossing over between pairs of homologous chromosomes to form chiasmata (form between two nonsister chromatids at points where they have crossed over)
- synaptonemal complex is complete and can be stable for some time.
- Autosomal non-sister chromatids of homologous chromosomes can now extensively exchange segments in regions of homology.
- Only small regions of non-paired sex chromosomes interact
4- Diplotene:
- diplotene phase, diplonema; Greek, diplonema = "two threads"
- homologous chromosomes begin to separate but remain attached by chiasmata.
- synaptonemal complex degrades and the chromosomes separate from one another a small amount giving this appearance.
- It is possible that some chromosome uncoiling may also occur allowing some gene transcription.
  > In the developing human ovary, oocytes remain at the diplotene stage from fetal life through postnatal childhood, until puberty when the lutenizing hormone (LH) surges stimulate the resumption of meiosis.

5-Diakinesis:
- diakinesis phase; Greek, diakinesis = "moving through"
- homologous chromosomes continue to separate, and chiasmata move to the ends of the chromosomes.
- prophase I ends and chromosomes now recondense, transcription stops and the transition to metaphase occurs.
Metaphase I:

- Homologous pairs of chromosomes (bivalents) arranged as a double row along the metaphase plate. The arrangement of the paired chromosomes with respect to the poles of the spindle apparatus is random along the metaphase plate. (This is a source of genetic variation through random assortment, as the paternal and maternal chromosomes in a homologous pair are similar but not identical.

- The number of possible arrangements is $2^n$, where $n$ is the number of chromosomes in a haploid set. Human beings have 23 different chromosomes, so the number of possible combinations is $2^{23}$, which is over 8 million.)
- **Anaphase I:**
  - The homologous chromosomes in each bivalent are separated and move to the opposite poles of the cell.

- **Telophase I:**
  - The chromosomes become diffuse and the nuclear membrane reforms.

- **Cytokinesis I:**
  - Cellular cytoplasmic division to form two new cells, followed by Meiosis II.

  **Note** - in oocyte meiosis, the extrusion of the first polar body (1 PB) indicates completion of the first meiotic division.
**Meiosis, or sex cell division**

At the onset of meiosis, DNA strands thicken into chromosomes. Homologous, or like, chromosomes begin to approach each other.

Homologous chromosomes pair to form bivalents. The centrioles divide and move to opposite poles of the cell.

The bivalents duplicate to form tetrads, or four-chromatid groups. The nuclear membrane disintegrates. Crossing over (recombination) occurs.

In metaphase I, the tetrads, attached to spindle fibers at their centromeres, line up at mid-cell.

In early anaphase I, the tetrads separate, and the paired chromatids move along the spindle to their respective centrioles.

In late anaphase I, the chromatids have almost reached the spindle poles. The cell membrane begins to constrict.

In telophase I, nuclear membranes enclose the separated chromatids. The cell membrane completes its constriction.

The first meiotic division ends. There are now two cells, each with the same number of chromatids as the parent cell.

Prophase II begins. In the second meiotic division, homologous chromatids do not duplicate but merely separate.

In metaphase II, the chromatids line up at mid-cell. The centrioles and aster are at the poles. A spindle has formed.

In anaphase II, the now-separated chromatids approach their respective poles. The cell membrane begins to constrict.

Telophase II has been completed. There are now four cells, each with half the number of chromosomes of the parent cell.
Meiosis II:

- **Prophase II:**
  - Chromosomes begin to condense, nuclear membrane breaks down and spindle forms.

- **Metaphase II:**
  - Spindle fibres attach to chromosomes, chromosomes align in cell centre.

- **Anaphase II:**
  - Chromosomes separate and move to the opposite poles of the cell.

- **Telophase II:**
  - Chromosomes reach spindle pole ends and the nuclear membrane reforms.

- **Cytokinesis:**
  - Cellular cytoplasmic division to form new cells.
## Compare between the mitosis & meiosis:

<table>
<thead>
<tr>
<th>Mitosis</th>
<th>Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- one division.</td>
<td>1- two division</td>
</tr>
<tr>
<td>2- two daughter cells per cycle.</td>
<td>2- Four daughter cells per cycle.</td>
</tr>
<tr>
<td>3- Daughter cells genetically are identical.</td>
<td>3- Daughter cells genetically are different.</td>
</tr>
<tr>
<td>4- Chromosome number of daughter cells same as that of parent cells(2n).</td>
<td>4-4- Chromosome number of daughter cells is half of parent cell(n).</td>
</tr>
<tr>
<td>5- Occurs in somatic cells.</td>
<td>5- Occurs in germline cell.</td>
</tr>
<tr>
<td>6- Occurs through out life cycle.</td>
<td>6- In human, completes after sexual maturity.</td>
</tr>
<tr>
<td>7- Used for growth, repair &amp; a sexual reproduction.</td>
<td>7- Used for sexual reproduction, producing new gene combinations.</td>
</tr>
</tbody>
</table>
Female (oogenesis):

- Meiosis initiated once in a finite population of cells
- 1 gamete produced / meiosis
- Completion of meiosis delayed for months or years
- Meiosis arrested at 1st meiotic prophase and reinitiated in a smaller population of cells
- Differentiation of gamete occurs while diploid in first meiotic prophase
- All chromosomes exhibit equivalent transcription and recombination during meiotic prophase
Male (spermatogenesis):

- Meiosis initiated continuously in a mitotically dividing stem cell population
- 4 gametes produced / meiosis
- Meiosis completed in days or weeks
- Meiosis and differentiation proceed continuously without cell cycle arrest
- Differentiation of gamete occurs while haploid after meiosis ends.
- Sex chromosomes excluded from recombination and transcription during first meiotic prophase.
Female Gametogenesis:

- In females, the total number of eggs ever to be produced are present in the newborn female.
- All eggs are arrested at an early stage of the first meiotic division as a primary oocyte (primordial follicle). Following puberty, during each menstrual cycle, pituitary gonadotrophin stimulates completion of meiosis 1 the day before ovulation.
- In meiosis 1, a diploid cell becomes 2 haploid (23 chromosomes) daughter cells, each chromosome has two chromatids. One cell becomes the secondary oocyte the other cell forms the first polar body.
- The secondary oocyte then commences meiosis 2 which arrests at metaphase and will not continue without fertilization.
- At fertilization meiosis 2 completes, forming a second polar body. Note that the first polar body may also undergo this process forming a third polar body.
Human oocyte at metaphase II showing polar body at 12 o'clock position.

The breakdown of the germinal vesicle indicates a resumption of meiosis and the extrusion of the first polar body (1 PB) indicates completion of the first meiotic division in human oocytes. The polar body is a small cytoplasmic exclusion body formed to enclose the excess DNA formed during the oocyte (egg) meiosis and following sperm fertilization.

There are 2-3 polar bodies derived from the oocyte present in the zygote, the number is dependent upon whether polar body 1 (the first polar body formed during meiosis 1) divides during meiosis 2. This exclusion body contains the excess DNA from the reductive division (the second and third polar bodies are formed from meiosis 2 at fertilization). These polar bodies do not contribute to the future genetic complement of the zygote, embryo or fetus.

Recent research in some species suggest that the space formed by the peripheral polar body (between the oocyte and the zona pellucida) can influence the site of spermatozoa fertilization.

Assisted reproductive techniques involving intracytoplasmic sperm injection (ICSI) have looked at the "quality" of the polar body and found that the morphology is related to mature oocyte viability and has the potential to predict oocyte fertilization rates and pregnancy achievement.
Female Abnormalities:

- Trisomy 21 female karyotype
- Meiotic non-disjunction resulting in aneuploidy, most are embryonic lethal and not seen. The potential for genetic abnormalities increase with maternal age.
- Autosomal chromosome aneuploidy
  - trisomy 21 - Down syndrome
  - trisomy 18 - Edwards syndrome
  - trisomy 13 - Patau syndrome
- Sex chromosome aneuploidy
  - monosomy X - Turner's Syndrome
  - trisomy X - Triple-X syndrome
  - 47 XXY - Klinefelter's Syndrome
Trisomy 21 (Down Syndrome)

- Most common.
- Affected persons have trisomy 21 (3 chr. No.21).
- Chromosome count is 47.
- Cause is meiotic nondisjunction.
- Maternal age has a strong influence on the incidence of Down Syndrome.
Trisomy 21 (Down Syndrome)
Klinefelter Syndrome:

- Male hypogonadism.
- Most patients are 47, xxy in karyotype.
- Cause nondisjunction of sex chromosomes during meiosis.
- Advanced maternal age and the history of irradiation of either may contribute to the meiotic error.
Klinefelter Syndrome

Phenotype

- Frontal baldness absent
- Poor beard growth
- Tendency to grow fewer chest hairs
- Narrow shoulders
- Breast development
- Wide hips
- Long arms and legs

Genotype

- XXXY karyotype
Turner Syndrome:

- Karyotype is 45x.
- Cause: Monosomy of x chromosome.
- Hypogonadism in phenotypic females.
Turner Syndrome:

Genotype

phenotype

Genotype

Phenotype
In males, sperm continues to be generated throughout life from a stem cell population in the testis. Spermatozoa maturation involves two processes: meiosis and spermiogenesis.
Human Spermatozoa Development:

- Spermatogenesis process of spermatagonia mature into spermatozoa (sperm).
- Continuously throughout life occurs in the seminiferous tubules in the male gonad—testis (plural testes).
- At puberty spermatagonia activate and proliferate (mitosis).
- About 48 days from entering meiosis until morphologically mature spermatozoa.
- About 64 days to complete spermatogenesis, depending reproduction time of spermatogonia.
- Follicle stimulating hormone (FSH) - stimulates the spermatogenic epithelium.
- Luteinizing-hormone (LH) - stimulates testosterone production by Leydig cells.
Mature human spermatozoa:

- Mature human spermatozoa: 60 µm long, actively motile
- Divided into 3 main regions (head, neck and tail)
- Head - (flattened, 5 µm long by 3 µm wide) the nucleus and acrosome. Posterior part of nuclear membrane forms the basal plate.
- Neck - (1 µm) attached to basal plate, transverse oriented centriole, contains nine segmented columns of fibrous material, continue as outer dense fibres in tail.
- Tail - 3 parts a middle piece, principal piece and end piece
  - Middle piece - (5 µm long) axonema and dense fibres surrounded by mitochondria
  - Principal piece - (45 µm long) fibrous sheath interconnected by regularly spaced circumferential hoops
  - End piece - (5 µm long) axonema surrounded by small amount of cytoplasm and plasma membrane
Male Abnormalities:

- **Oligospermia** - (Low Sperm Count) less than 20 million sperm after 72 hour abstinence from sex.
- **Azoospermia** - (Absent Sperm) blockage of duct network.
- **Immotile Cilia Syndrome** - lack of sperm motility.
Thank you