Cell Divisions

Each Cell (including gonads) has 46 chromosomes (23 pairs of chromosomes: 22 pairs of autosomes, 1 pair of sex chromosomes) which are located in the nucleus).

The autosomes represent the whole body.
* Male Sex Chromosomes: XY
* Female Sex Chromosomes: XX

- The traits of an individual are the genetic features that are inherited to the embryo (initially zygote); either Paternal (from the father via sperm, X or Y) or Maternal (from the mother via mature ovum, only X).

- Humans have around 35,000 genes on 46 chromosomes.

Chromosomes contain DNA codes (deoxyribonucleic acid) that specify the function of the cell. Example: if we took a cell from the mucosa of oral cavity and examine it under a microscope, we would find a nucleus that contains 46 chromosomes (if it is taken from a male, the sex pair is XY and if it is taken from a female, it is XX), the remaining 22 pairs (autosomes) reflect the function of this cell which is the secretion of mucus.

The cell divides (mitosis) as a result of an injury, then a specific protein stimulates the cell to stop division (if it's not controlled by this protein, it will be malignant).

** The Anatomy of the chromosome:

It has 2 sister chromatids attached by a centromere. Each chromatid has a short arm/or upper limb (P-arm, upward) and a long arm/or lower limb (Q-arm, downward)
Note: the Arm is a helical series of amino acids (The Dr. said it is "amino acids", but he mostly meant Nucleic Acids since he then said DNA).

Telomere: the tip of the arm.

The Chromosome is an arrangement of groups of DNA. DNA contains the code of the cell function. Then when the cell divides, it gives 2 daughter cells (each has the same function of the mother cell)

** Somatic cell has 23 pairs of chromosomes (22 pairs are homologous (autosomes), 1 pair is non-homologous (sex chromosomes))
* Diploid (2n): 2 sets of chromosomes (in humans: 46 chromosomes)

* Haploid (1n): 1 set of chromosomes (in humans: 23 single chromosomes) “half amount of DNA”

** in Gonads (ovary and testis)

at the beginning, the gonad has 46 chromosomes. If it enters the mitosis, it gives 2 cells (each has the same number of chromosomes).

If it enters the meiosis division, it gives 2 cells have the half number of chromosomes (23 single chromosomes)

** At the beginning of Mitosis, DNA replication occurs. Thus, every chromatid forms the same chromosome in the new cells produced by division (so, the new cells are same in : function, number of chromosomes, structure).

** The Gene is a DNA that transfers the inherited traits form one generation to another generation.

** Every Cell has 22 Matching chromosomes ,but the sex pair is not a matching chromosome.

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*In Females:

in ovary ⟶ XX ⟶ each cell is called Oogonium ⟶ Comes from the germ cell (located in the wall of the yolk sac of the Embryo) ⟶ the Oogonium gives Primary Oocytes ⟶ each primary gives 2 secondary Oocytes ⟶ they give 4 (3 are called polar bodies and they disintegrate and only 1 becomes a mature ovum (23 single chromosomes: 22 autosomes, 1 sex “X”)

*In Males:

in Testis ⟶ XY ⟶ each cell is called spermatogonium ⟶ gives the primary spermatocytes ⟶ each primary gives 2 secondary spermatocytes (1n) ⟶ each secondary gives 2 sperms (4 sperms produced from 1 primary)

Note:

each sperm has 23 single chromosomes: 22 autosomes, 1 sex chromosome (in males, it may be X or Y) . Thus, the 4 sperms produced from one primary spermatocyte, two of them are X and two are Y). Notice that the sperm specifies the sex of the embryo.

** in fertilization, the mature ovum and the sperm form the zygote which has the diploid number of chromosomes (46 chromosomes).

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The Cell Cycle:

Phases of cell cycle: interphase (includes: G1, S, G2) and mitosis (includes: prophase, metaphase, anaphase, telophase and the cytoplasmic division).

* Interphase (before division) : most of our cells are in the interphase. Then the cells enter the mitosis phase.
  The first Step of Division is Replication of DNA.

** At the end of mitosis, each cell gives 2 identical daughter cells (same no. of chromosomes, same genetic info., same function) as mentioned.

** The interphase:
  G1 period: before DNA replication (8-10 hours)
  S period: DNA is duplicated after it is stimulated.
  G2 period: prepare cells for division
  * G0 period: when the cell exit from the cycle (Non-dividing cell).

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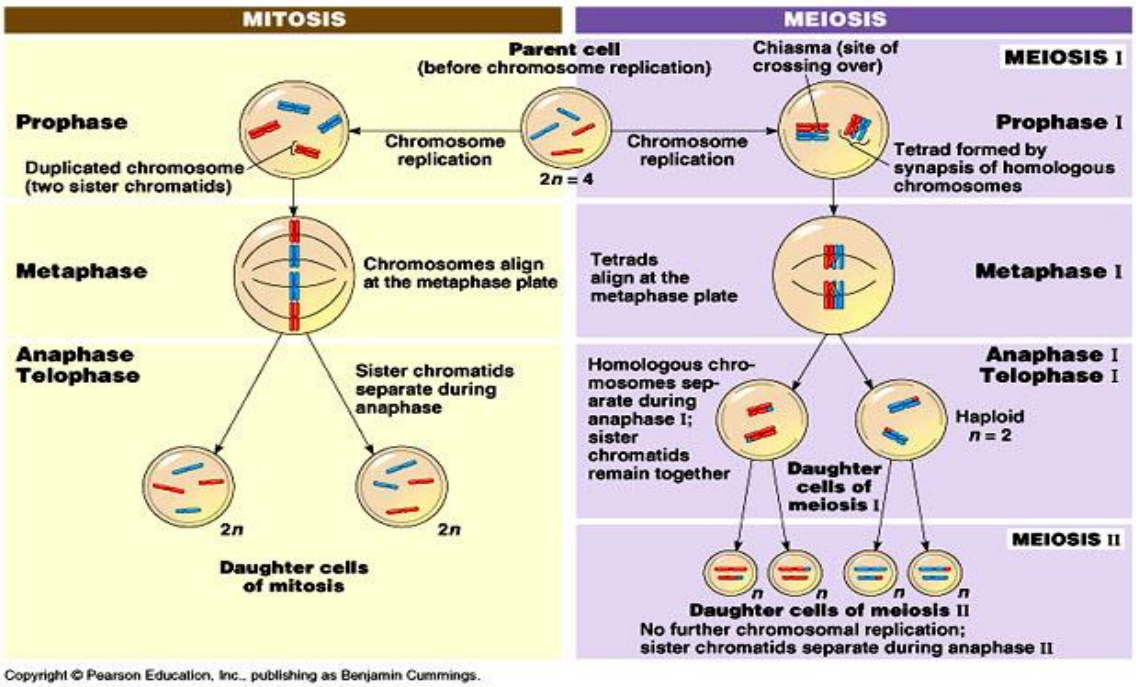
Mitosis and Meiosis:

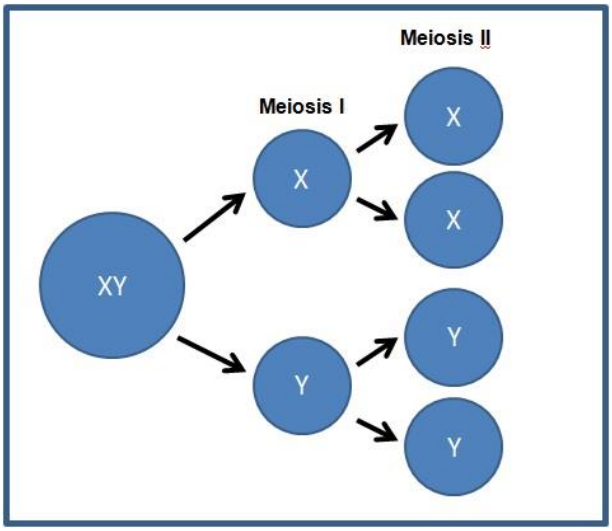


In Brief:
Mitosis: at the end, 2 daughter cells produced (2n)
Meiosis: at the end, 4 cells produced (1n)

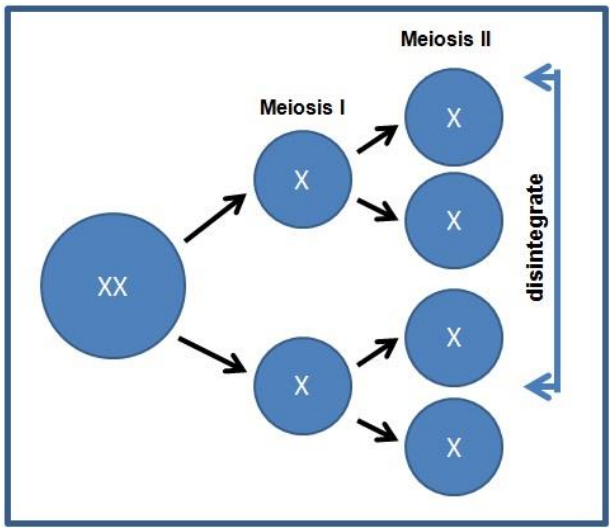
** one important thing in meiosis is the tetrads (by synapsis and crossover of the homologous chromatids). At the end of meiosis I, 2 daughter cells produced (the primary gives 2 secondary cells (1n)). Then the produced cells enter meiosis II (like mitosis), each cell gives 2 cells (1n). the overall number of the cells after meiosis division is 4 cells.

** Note:

in males:



in Females:



**Mitosis:

1- prophase
2- prometaphase (chromatids become distinguishable)
3- Metaphase: the chromosomes line up in the equatorial plane.

Note: every chromatid in the same chromosome has the same DNA (because of the replication). So when the cell divides, each chromatid forms the same chromosome in the new daughter cells.

*centrioles form mitotic spindles. Its function is to separate the two sister chromatids.

4- Anaphase: separation of the sister chromatids (includes the division of centromere): one at one pole of the cell and the other at the opposite pole.

5- Telophase: the nuclear envelope reforms then the cytoplasm divides.

Finally, the cell gives two daughter cells (2n), each has the same DNA of the mother cell.

** Meiosis (performed by gonads): Meiosis l, Meiosis ll.
Primary spermatocytes and oocytes at the the beginning, replicate their DNA.
Every 2 homologous chromosomes align in pairs (synapsis) or crossover by the two homologous chromatids (non-sister chromatids of two homologous chromosomes).

* the pairing doesn't include the sex chromosomes (XY) because they are non-homologous.

Crossover between chromatids of homologous chromosomes.
** Chiasma formation: X-like structure where points of interchange are temporarily united.
Then we have the pulling apart double-structured chromosomes. So, the DNA is transmitted between the homologous chromatids.

The importance of crossover:
It's the reason that makes each individual differing from another. (although sons and daughters have similarities with their parents, there are differences due to the crossover)

As a result of meiosis:
1- genetic variability by crossover;
2- germ cell contains haploid no. of chromosomes (1n);
3- in fertilization, the diploid no. is restored.

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*The centromere division (disjunction)
in Mitosis: it divides directly (in anaphase)
in Meiosis: it divides in meiosis ll after the formation of the secondary cells (anaphase ll)

* there is one centomere between the sister chromatids then it divides from the middle.

Spermatogenesis

Is Meiosis in the seminiferous tubule in the testis

Primordial germ cell migrates from the wall of the yolk sac. It arrives at the testis in the 5th week during the development of the embryo and increases its number by mitosis. It is located between the supporting cells (sertoli cells) which are located in the wall of the testis.

By mitosis, the germ cell gives the spermatogonia (2n) (it changes from dark to pale to A to B spermatogonia). But meiosis of germ cells occurs only at puberty age. (The individual stays at the primordial germ cell stage (dormant) and may give spermatogonium).

At puberty age (in males), the pituitary gland secrets gonadotropic hormone (GTH) and luteinizing hormone (LH) which stimulate cells in the testis outside the seminiferous tubules beside the basement membrane called Leydig cells in the wall of testis.

Leydig cells secrete testosterone which stimulates the transformation of spermatogonia into primary spermatocytes (46 chromosomes) by mitosis. Then the primary spermatocytes enter meiosis l to produce two secondary spermatocytes (1n) and they enter meiosis ll and produce 4 spermatids (1n) which develop into spermatozoa.

In other words:
The **germ cell** stays dormant, then, under effects of hormones, it transfers into the **primary spermatocyte** by a specific protein. The primary spermatocyte enters meiosis and produces 2 **secondary spermatocytes.** Each secondary spermatocyte gives 2 **spermatids** (4 spermatids are produced from one primary spermatocyte) which mature to give **spermatozoa** (sperms).
We have millions of cells, thus, 100 billions of sperms are produced.
“Spermatogenesis begins at puberty age (spermatogonia transform into spermatozoa “sperms”)”

** Sertoli Cells (supporting cells “connective tissue”): produced by basement membrane and located in the wall of seminiferous tubules.

Functions of sertoli cells:
1- give nutrients to the cells
2- support
3- defense
4- microphages

* Sertoli cells attract and attach to spermatids until they transform into spermatozoa (sperms) (cytodifferentiation) the they are released (spermiation) so they become able to swim to the lumen of seminiferous tubule and then to the epididymis for maturation .

** spermatogonia types:
1- type A spermatogonia (dark , pale) : give type B spermatogonia
2- type B spermatogonia: give the primary spermatocytes by mitosis (46 chromosomes)

- Type B produced from the mitosis of type A by a specific protein , each type B spermatogonia gives 2 primary spermatocytes (by a specific protein). Each spermatocyte enters the meiosis to form 2 secondary spermatocytes. Spermatocytes produce spermatids (attached to sertoli cells “immature” and unable to move). Spermatids convert into spermatozoa (sperms) by sloughing of residual bodies (kind of cytoplasm). The sperms swim to the epididymis to complete maturation.

**Question: One type B spermatogonium, how many sperms produced?
Answer: 8 sperms (4: X , 4: Y)

** Luteinizing hormone (LH) and follicle stimulating hormone (FSH) effect more in Females but they effect in the testis (help in secretion of testosterone and intercellular androgen proteins)

*Cytodifferentiation : Changes resulting in the transformation of spermatids into spermatozoa.

** The Changes During cytodifferentiation:
1- formation of acrosome (cap over the head of the sperm) contains lytic enzymes help in penetration into the mature ovum.

2- Condensation of the nucleus (in the head) which is important because it is the home of chromosomes (23 single chromosomes)

3- formation of neck (middle piece) and tail (the middle piece contains large number of mitochondria to give energy for swimming)

Spermatogonium development into mature spermatozoon takes 64 days. Because of the huge number of cells, this process and the storage of sperms never stop.

** The maturation in epididymis takes 10 – 14 days. Then, the spermatozoa move through testicular fluid which is produced by sertoli cells. The fluid contains steroids, proteins, ions, ABP and testosterone.

** Sperms live for 48-72 hours.

** Factors Effect spermatogenesis
1- temperature (the testis is located in the scrotum outside the body and the production of sperms occurs 2-3 degrees below the body temperature.
** Varicocele is a common disease that occurs because of the effect of temperature (temperature increase kills the sperms) and it can be fixed by a specific operation.

2- Vitamin E: it stimulates secretion of testosterone, so it contributes in spermatogenesis

3- FSH, LH (as mentioned)

4- Toxins that kill sperms, x-rays, vitamin deficiency and injuries (direct trauma on the testis).

** Testis barrier (junctional complex) is produced by junctions of sertoli cells and it is located between spermatogonia and other cells that enter the meiosis. It prevents the effect of bacteria and viruses on the division (meiosis).
Mitosis happens in large numbers, so it isn't affected by these agents. (the cells that enter mitosis are located between basement membrane and the junctional complex)

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