GENETICS

Sheet no. 4

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Cell Division

Sexual Reproduction

After finishing the mitosis, we will start with the meiosis, and we saw that the outcome of mitosis is producing 2 identical cells to the maternal and paternal cells (clones of them) which are identical in the number of chromosomes and the sequence.

• During the many rounds of cell division within an embryo, most cells either grow and divide via the mitotic cell cycle just described

– Somatic cells whose descendants continue to make up the vast majority of each organism's tissues throughout the lifetime of the individual.

• Sexual reproduction is the most common way for eukaryotic organisms to produce offspring

– Germ cells are precursors to gametes

– Become incorporated into reproductive organs (ovaries and testes in animals)

– where they ultimately undergo meiosis

Meiosis

-happens in germ cells(Diploid, 2n) to produce ova and sperms (each one is haploid, 1n), then after fertilization, they give zygote(2n), taking 9 months window of time to produce the multi-cellular organisms of the human being by millions of billions of cell divisions from mitosis to produce organisms.

• The special two-part cell division that produces gametes (eggs and sperm)

• Meiosis produces haploid cells (containing half the number of chromosomes) from a cell that was originally diploid

• Like mitosis, meiosis begins after a cell has progressed through interphase (G1, S, and G2) of the cell cycle

– but in meiosis, Chromosomes duplicate once:

- the cell enters the first round of the cell cycle and then the second round of the cell cycle and the chromosomes duplicate only once before entering the first round, meaning that there is no duplication between rounds.

-in mitosis, there is S phase for duplication then division starts.

-mitosis produces diploid cells(2n) identical to the maternal cell in terms of numbers and sequence, while in meiosis, 4 haploid cells are produced(1n), and they are genetically different from the maternal cell.

- meiosis has two successive rounds of cell divisions, opposite to mitosis only one round, while the first round we call meiosis 1, where chromosomes are reduced to half by separating the homologous chromosomes individually into different cells, calling this round **reductional cell division.**

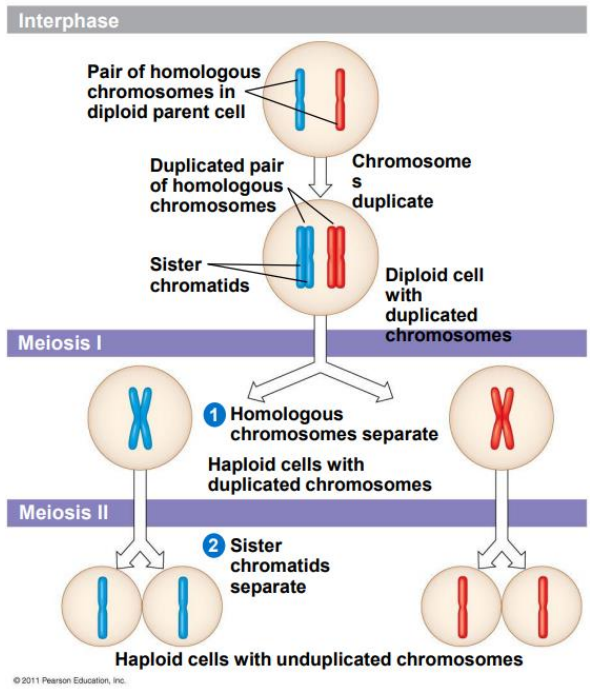
-Meiosis 2 is called equational divisions because there is no decrease in the number of chromosomes between the cells from 1n to 1n and so results in 4 Haploid daughter cells with unreplicated chromosomes.

Unlike mitosis, meiosis involves two successive divisions

– Meiosis I (reductional division): homologs pair up and separate, resulting in two haploid daughter cells with replicated chromosomes

– Meiosis II (equational division) sister chromatids separate

• The result is four haploid daughter cells with unreplicated chromosomes



In interphase, starting with pair of homologous chromosomes(maternal and paternal) then in the S phase the chromosomes are duplicated, then pass to the G2 phase, the sister chromatids are shown, after that the homologous chromosomes are disjoined giving 2 haploid cells(meiosis 1), going further to in meiosis 2, the sister chromatids are separated giving 4 haploid cells genetically different from the stem cell.

-notice that meiosis 2 preserves the number of chromosomes, it is identical to mitosis.

-dealing with numbers, starting with 46 chromosomes→ duplicated to 92 chromatids in 46 homologous chromosomes→divided in meiosis 1 by separating homologous chromosomes into 23 chromosomes having 46 chromatids→ and finally in meiosis 2 the sister chromatids will be separated giving 23 chromosomes in each cell of the 4 cells.

-q1: where did the reduction happen? In meiosis 1

-How are the number of chromosomes preserved in meiosis2? Bcz it separates sister chromatids

--your chance to compare:

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meiosis	mitosis
2 stages(reductional and equational)	1 round
reproduction	Growth,..refer to lec2 part 1
4 haploid cells	2 diploid cells
Genetically different from the maternal cells	Clones of the maternal cells

Then progenitor cells (germline cells, diploid) undergo meiosis 1 and meiosis 2, dividing into several stages similar to mitosis (the prophase, metaphase, anaphase, and telophase in the two rounds.

Prophase I is further subdivided into periods known as

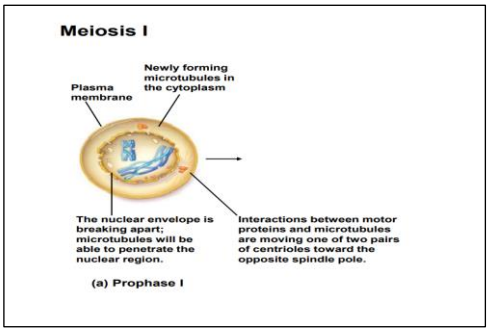
– Leptotena

– Zygotena

– Pachytena

– Diplotena

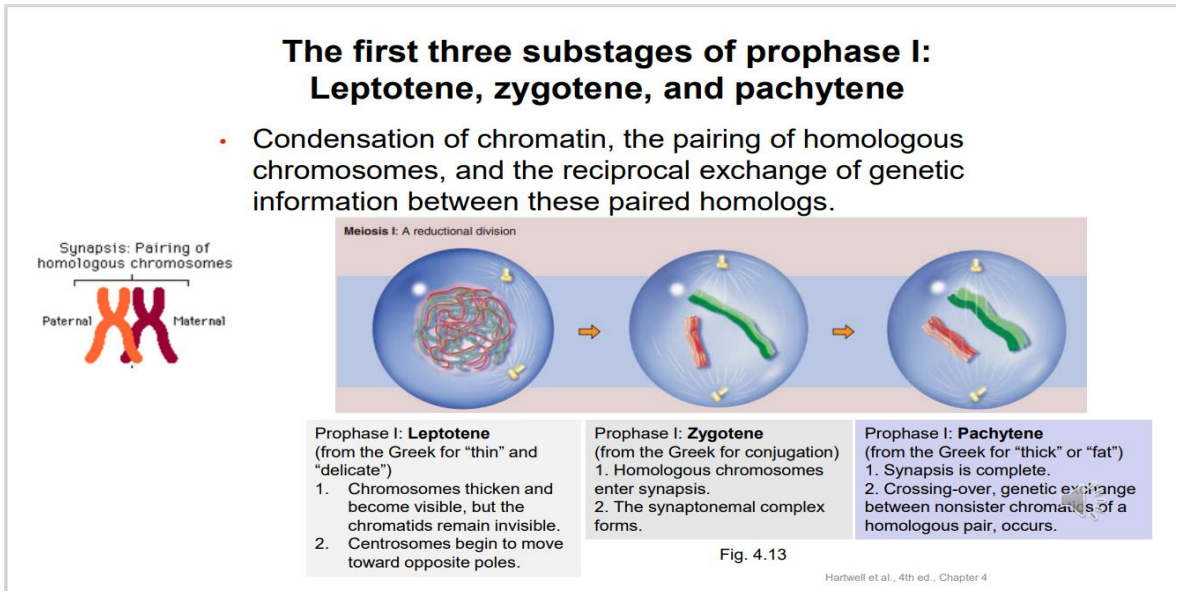
– Diakinesis



In prophase 1 we can see the homologous chromosomes are joining or attaching or lining to each other where they hold together by what we call synaptonemal complex and the other changes are similar to mitosis we can see the nuclear envelope starts to degrade, Centrioles appear.

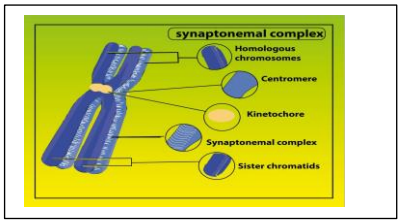
-can see major important things that could have happened during the prophase one :crossing over to exchange genetic material between the homologous chromosomes.

-so the feature of prophase 1 is condensation of chromatins, homologous chromosomes and reciprocal exchange of genetic information between the non sister chromatids of the homologous chromosome.



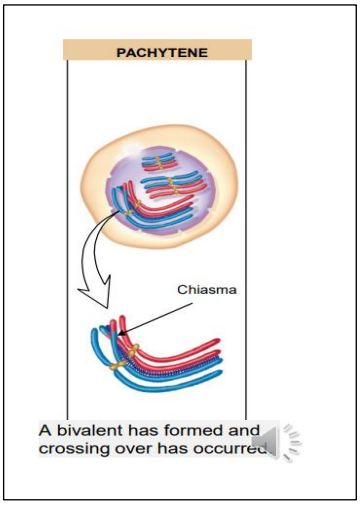
1-leptotene: the 1st stage of prophase 1, which means Greek thin threads, indicating that the chromosomes appear as delicate threads, also the spindle fibers start to be projected from the centrioles, and they are directed towards the poles

2-zygotene: means in Greek hairy threads, which is characterized by synapse formation called synaptonemal complexes which are protein structures helping to hold the aligned homologous chromosomes together



3-pachytene: the chromosomes become thicker, and the synapses are completed, so they start to form in zygotene but cove all chromatin in pachytene.

-also in pachytene, the 2 homologous chromosomes form BIVALENT, or TETRAD(4 chromatids),however, the tetrads are still not clear, they become more clear in diplotene, and by their aligning, they facilitate the genetic material exchange(crossing over) which happens between **non-sister chromatids.**



Pachytene

• During pachytene: each synapsed chromosome pair is known as a bivalent (because it encompasses two chromosomes), or a tetrad (because it

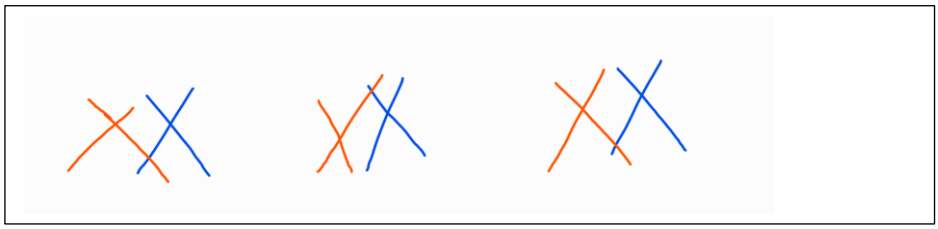
contains four chromatids).

• Structures called recombination

nodules (chiasmata) begin to appear

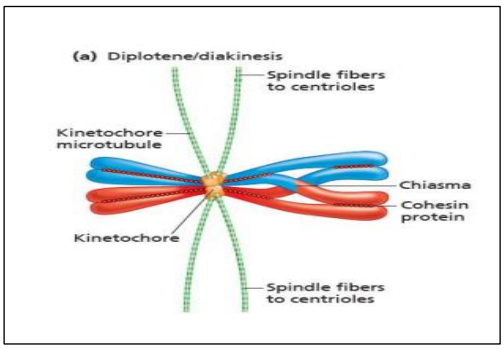
along the synaptonemal complex, and

an exchange of parts between nonsister (that is, between maternal and paternal) chromatids occurs at these nodules.



so here, 3 homologous chromosomes bind to their counterparts by synaptonemal complex completely, and there is a meeting point between the non-sister chromatids called chiasma, where crossover happens.

-where does the crossing over happen accurately? In meiosis 1, prophase1, in pachytene.



Diplotene and Diakinesis

Diplotene

• Synaptonemal complex dissolves.

• A tetrad of four chromatids is visible.

• Nonsister chromatids appears to pull

apart slightly but remains connected at chiasmata.

Why? Bcz the next step is metaphase, to avoid disjoining and rejoining between the homologous chromosomes, also the kinetochores are attached to the homologous chromosomes to the centromere from centrioles in diplotene and diakinesis.

• Meiotic arrest occurs at this time in many species

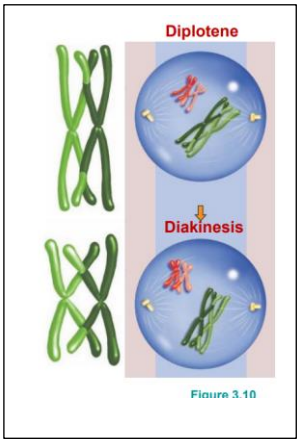
Diakinesis

• Further condensation of chromatids.

• Chromatids thicken and shorten

• Nonsister chromatids remain closely associated at chiasmata.

• The end of diakinesis is analogous to the prometaphase of mitosis:



In the prometaphase, complete disintegrations or degradation

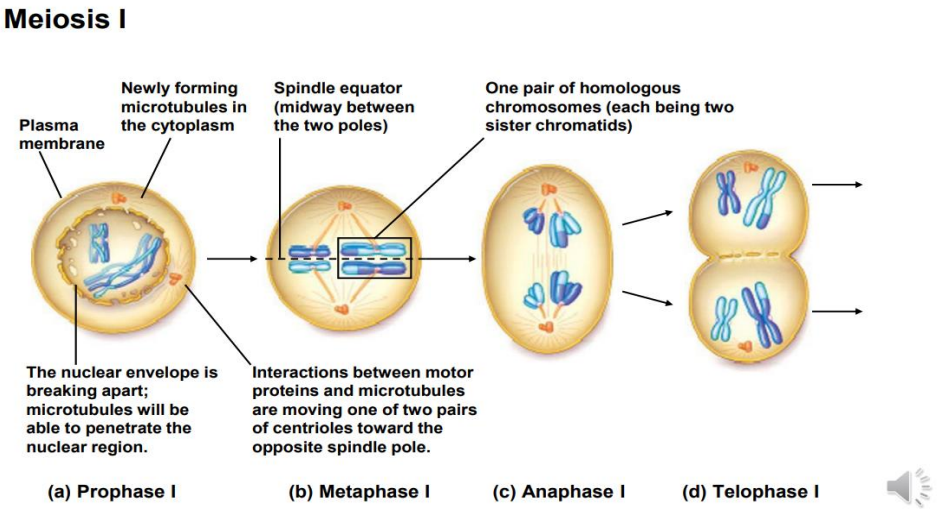
of the nuclear envelope happens and the spindle apparatus

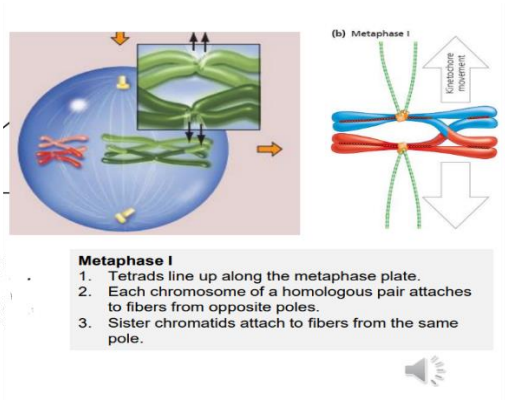
completely form

- **The nuclear envelope breaks down, and the microtubules of the spindle apparatus.**
- **These processes can take many days, months, or even years**

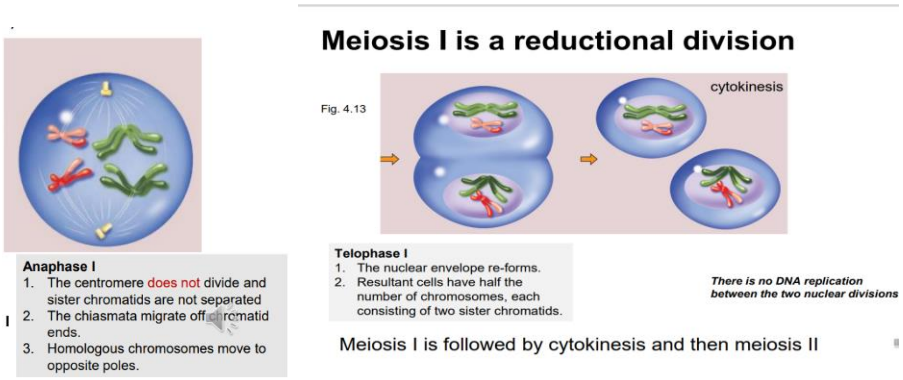
to complete.

- **For example, in the human females germ cells, meiosis is suspended at prophase I until ovulation <u>not G2</u>**





to opposite pole



Notes: in metaphase in mitosis, sister chromatids of an individual chromosome are aligned in one row to get separated, while in metaphase1 in meiosis, the homologous chromosomes align in 2 rows to get separated in anaphase1.

-in anaphase 1, The centromere doesn't divide because the kinetochore binds with the centromere of each homolog or each bivalent one of the poles of the spindle and the sister chromatid is still in contact with each other. So there is no dissolving for the cohesion proteins.

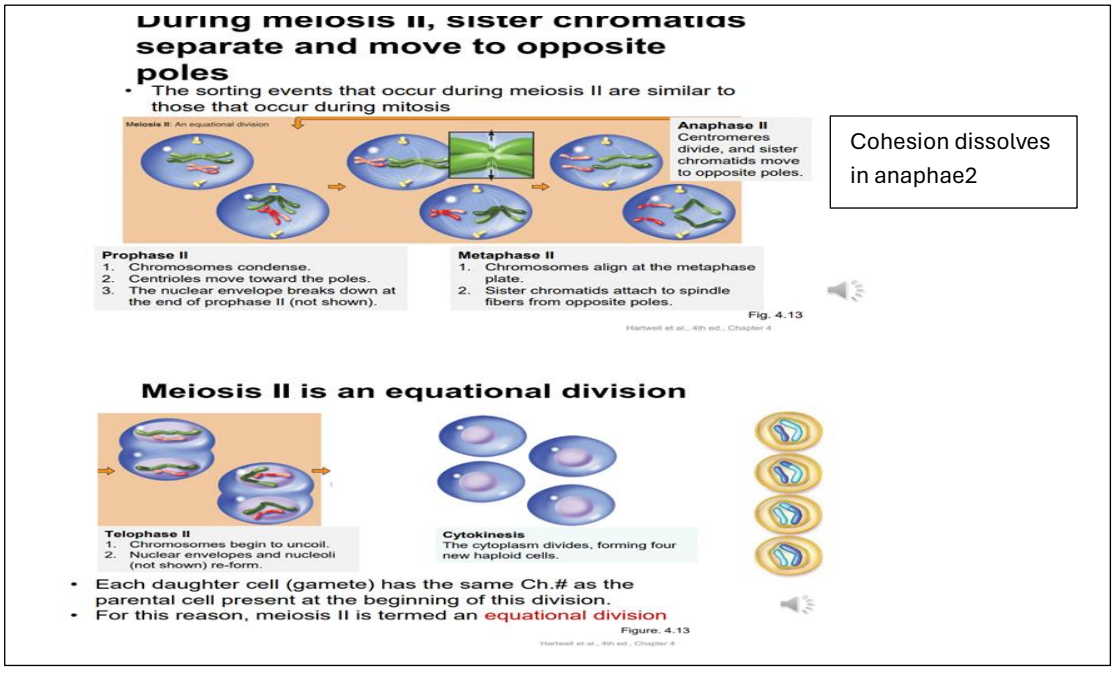
-homologous chromosomes are pulled to the opposite pole of the spindle then followed by cytokinesis.

-now, after the end of the 1st round, no duplication will happen, and generally, THERE IS NO GAP in time between meiosis 1 and 2, except in some organisms just a process of condensation and decondensation occurs.

Meiosis 2

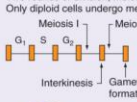
-same as mitosis

-equational division

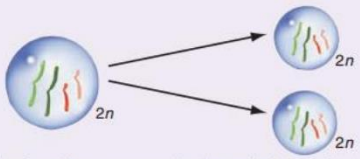


Cohesion dissolves in anaphae2

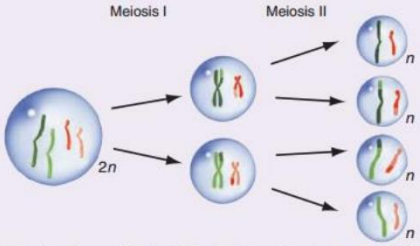
Comparison of mitosis and meiosis

Mitosis	Meiosis
Occurs in somatic cells Haploid and diploid cells can undergo mitosis One round of division	Occurs in germ cells as part of the sexual cycle Two rounds of division, meiosis I and meiosis II Only diploid cells undergo meiosis
 Mitosis is preceded by S phase (chromosome duplication).	 Chromosomes duplicate prior to meiosis I but not before meiosis II.
 Homologous chromosomes do not pair.	 During prophase of meiosis I, homologous chromosomes pair (synapse) along their length.
Genetic exchange between homologous chromosomes is very rare.	 Crossing-over occurs between homologous chromosomes during prophase of meiosis I.

Mitosis	Meiosis
 Sister chromatids attach to spindle fibers from opposite poles during metaphase.	 Homologous chromosomes (not sister chromatids) attach to spindle fibers from opposite poles during metaphase I.
 The centromere splits at the beginning of anaphase.	 The centromere does not split during meiosis I.
	 Sister chromatids attach to spindle fibers from opposite poles during metaphase II.
	 The centromere splits at the beginning of anaphase II.



Mitosis produces two new daughter cells, identical to each other and the original cell. Mitosis is thus genetically conservative.



Meiosis produces four haploid cells, one (egg) or all (sperm) of which can become gametes. None of these is identical to each other or to the original cell, because meiosis results in combinatorial change.

Consequences of meiosis

- **Reduction of chromosome number**
- **Diploid to haploid (essential for gametes)**
- **Random assortment of maternal and paternal chromosomes**

– Number of possible chromosomal combinations = 2^23 or 8,388,608

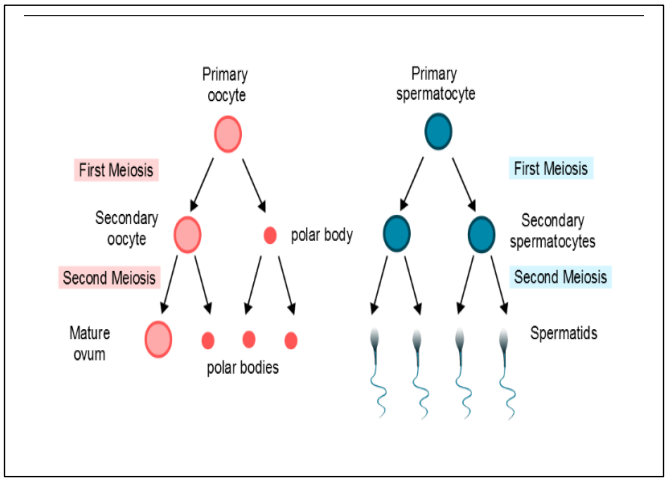
– Recombination between chromosome pairs increases the possible combinations

- **Segregation of alleles**
- **Recombination/crossing-over**

– Allows new combinations of genes to be produced

– Important for normal chromosome disjunction

– Ensures genetic diversity



-meiosis is important for gamete (Sperms and ova) formation

-sperm formation process is called: spermatogenesis starts

with primary spermatocytes(2n)→secondary

spermatocytes with meiosis 1(1n)→ mature spermatid →four sperms (23 ch.)

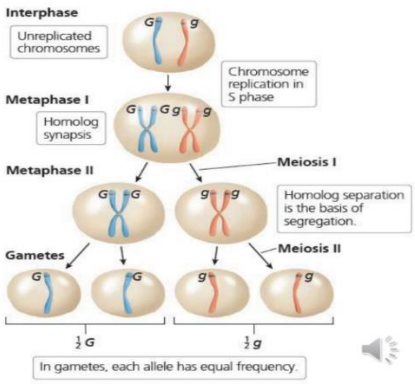
The ova formation process is oogenesis: primary oocytes→secondary oocytes→ mature ova

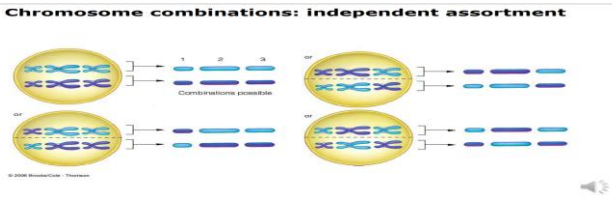
-oogenesis produces what we call a polar body, which is a cell that has less cytoplasm compared to the ovum(uneven cytoplasm), while in spermatogenesis, there is no polar bodies, bcz sperms don't have cytoplasm(only droplets), they have only head, tail, and the 1 n nucleus, while the Nutrients, RNA, proteins, and cytoplasm comes from the egg.

-the objective of meiosis is recombination, represented by Mendel's laws

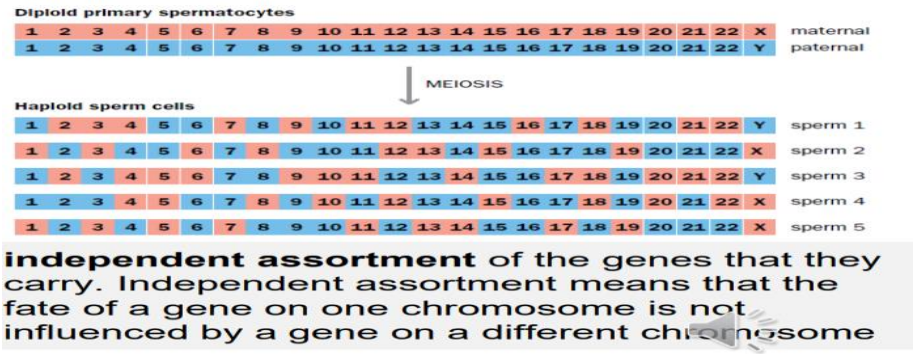
2^n, 2 for diploid cell , so 2^23= around 8 million represents the chance to have 2 identical brothers in the same family except for identical twins

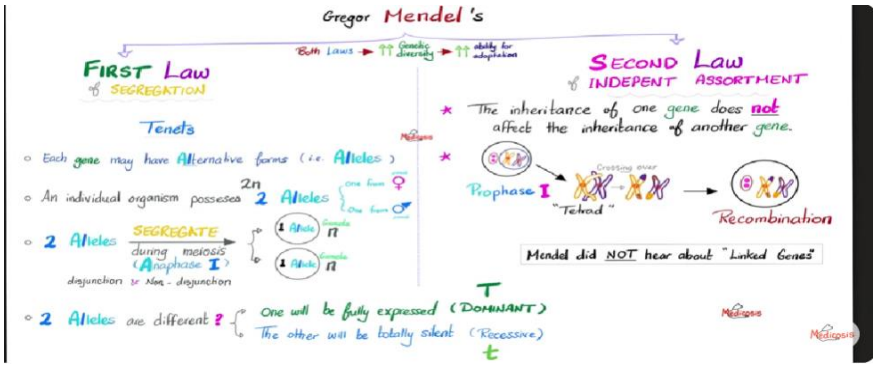
Law of Segregation





2^3=8 possiblities





https://youtu.be/2-R33y2lvnI?si=TNUcwkCvogOpJAvC

meiosis is important for the continuity of life for the variation between the individuals

the end

past paper:

- If GAMETE chromosomes are 16, what is the number of chromatids before anaphase 1?

A- 8

B- 16

C- 32

D- 64

E- 128

-Pair homologous chromosomes in metaphase I, how many double strand DNA in it?

A- 1 double strand DNA

B- 3 Double Strand DNA

C- 5 double strand DNA

D- 2 double strand DNA

E- 4 double strand DNA

-Recombination occurs in:

A- Pachytene

B- Zygotene

C- Diplotene

D- Leptotene

E- Diakinesis

-Law of segregation related to _____ and low of independent assortment related to:

A- Different chromosomes, homologous chromosomes

B- Homologous chromosomes, different chromosomes

-Imagine if the humans' diploid chromosomal complement is 10 instead of 46.

What would the number of possible combinatons of meiosis be:

a. 64

b. 32

c. 16

d. 4

e. 8

D E A B B

اللهمَّ لا يأتي رمضان إلا وغزة"

عالية راضية منصورة مجبورة

"مفتوح عليها بركات من السماء والأرض

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