The pomegranate (*Punica granatum*) is believed to have originated near Iran and southern Afghanistan.

The flowers are bright red with five petals. After the flower is fertilized with pollen the pomegranate fruit forms. They are usually between the size of an orange and a grapefruit, 7–12 cm in diameter with a rounded hexagonal shape, and have a thick reddish skin and many seeds. The edible parts of the fruit are the seeds and the red pulp surrounding them.

Pomegranates are prominent at Greek weddings where it is traditional to break a pomegranate on the ground at weddings as it is a symbol of abundance, fertility and good luck.

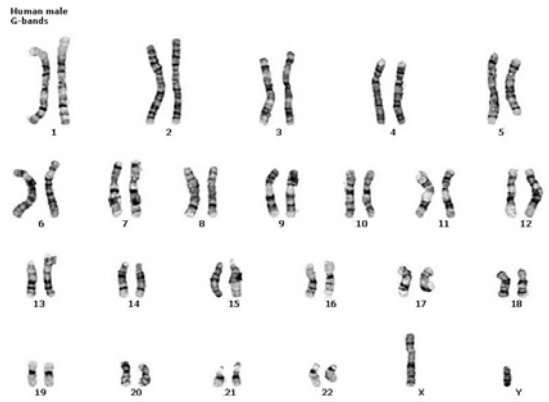
In this next unit we will take a look at the process used to create reproductive cells… Meiosis

Introduction

- A **life cycle** is the generation-to-generation sequence of stages in the reproductive history of an organism.
- It starts at the conception of an organism and continues until it produces its own offspring.

- In humans, each body cell (somatic cell) has 46 chromosomes.
- A **karyotype** display of the 46 chromosomes shows 23 pairs of chromosomes, each pair with the same length, centromere position, and staining pattern.
- These **homologous chromosome** pairs carry genes that control the same traits.

Human male karyotype shown by bright field G-banding of chromosomes



- Homologous pairs of chromosomes are the consequence of sexual reproduction.
- We inherit one chromosome of each homologous pair from each parent.
  - The 46 chromosomes in a somatic cell can be viewed as two sets of 23, a maternal set and a paternal set

Sperm and Egg cells (collectively called **gametes**) have only one set of chromosomes.

22 autosomes and one X or Y.

Cells with only **a single copy** of each chromosome are called **haploid**.

For humans, the haploid number of chromosomes is 23 (n = 23).

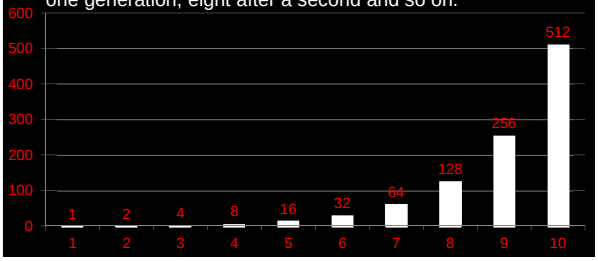
In sexual reproduction, a haploid sperm reaches and fuses with a haploid ovum.

The fertilized egg (called a **zygote**) now has two haploid sets of chromosomes containing genes from both the mother and father.

The zygote and all the cells in the body that have two sets of chromosomes are called **diploid cells**.

- For humans, the diploid number of chromosomes is 46 (2n = 46).

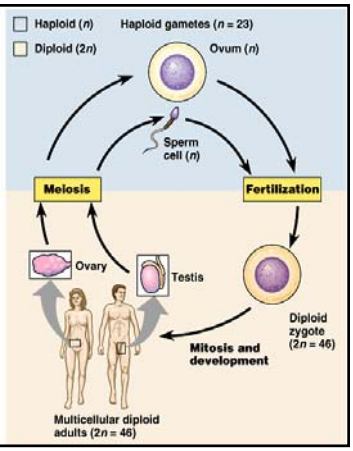
- As an organism develops from a zygote to a sexually mature adult, the zygote's genes are passed on to all somatic cells by mitosis.
- Gametes, which develop in the gonads, are ***not*** produced by mitosis.
- If gametes were produced by mitosis, the fusion of gametes would produce offspring with four sets of chromosomes after one generation, eight after a second and so on.



Instead of Mitosis, gametes undergo the process of **meiosis** in which the chromosome number is halved.

Human sperm or ova have a haploid set of 23 different chromosomes, one from each homologous pair.

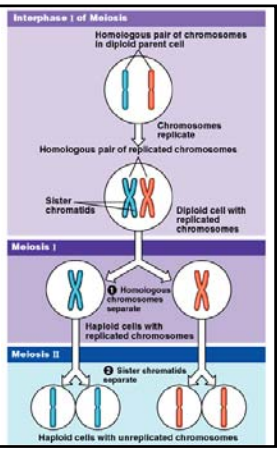
- Fertilization restores the diploid condition by combining two haploid sets of chromosomes.
- Fertilization and meiosis alternate in sexual life cycles.



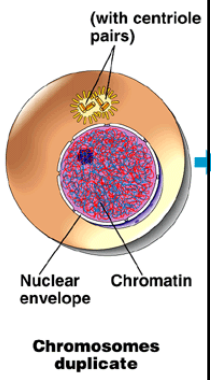
Meiosis reduces chromosome number from diploid to haploid

- Many of the steps of meiosis resemble steps in mitosis.
- However, in meiosis, there are **two** consecutive cell divisions, **meiosis I** and **meiosis II**, that result in four daughter cells.
- Each final daughter cell has only half as many chromosomes as the parent cell.

- Meiosis reduces chromosome number by copying the chromosomes once, but **dividing twice**.
- The first division, meiosis I, separates homologous chromosomes.
- The second, meiosis II, separates sister chromatids.

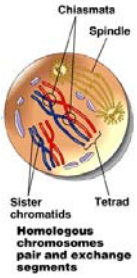


- Division in meiosis I occurs in four phases: prophase, metaphase, anaphase, and telophase.
- During the preceding interphase the chromosomes are replicated to form sister chromatids.
  - These are genetically identical and joined at the centromere.



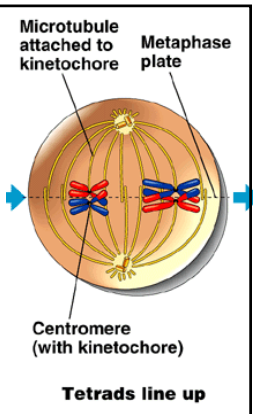
In prophase I, the chromosomes condense and homologous chromosomes pair up to form tetrads.

- At several sites the chromatids of homologous chromosomes are crossed and segments of the chromosomes are traded (**crossing over**).
- A spindle forms from each centriole and spindle fibers attached to centromeres on the chromosomes begin to move the tetrads around.

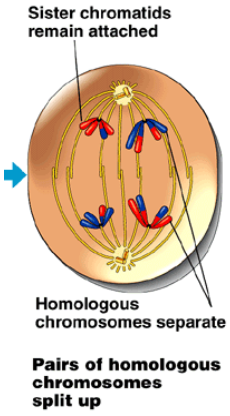


In metaphase I the tetrads are all arranged at the metaphase plate.

Microtubules from one pole are attached to the centromere of one chromosome of each tetrad, while those from the other pole are attached to the other.



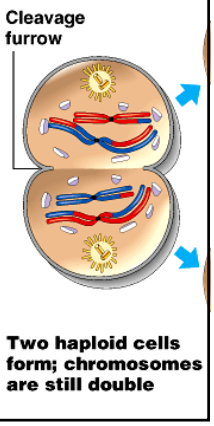
In anaphase I, the homologous chromosomes separate (but the sister chromatids remain together) and are pulled toward opposite poles.



In telophase I, movement of homologous chromosomes continues until there is a haploid set at each pole.

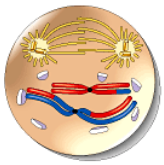
Each chromosome consists of linked sister chromatids.

Cytokinesis by the same mechanisms as mitosis usually occurs simultaneously.



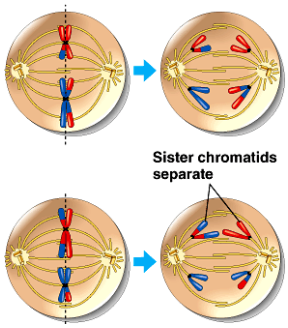
Meiosis II is very similar to mitosis.

During prophase II a spindle apparatus forms, attaches to centromeres of each sister chromatid, and moves them around.



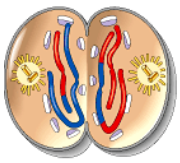
Spindle fibers from one pole attach to one sister chromatid and those of the other pole to the other sister chromatid.

- At metaphase II, the sister chromatids are arranged at the metaphase plate.
- At anaphase II, the centromeres of sister chromatids separate and the now separate sister chromatids travel toward opposite poles.



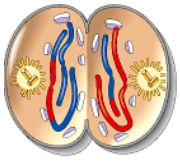
In telophase II, separated sister chromatids arrive at opposite poles.

Nuclear membranes form around the chromosomes.

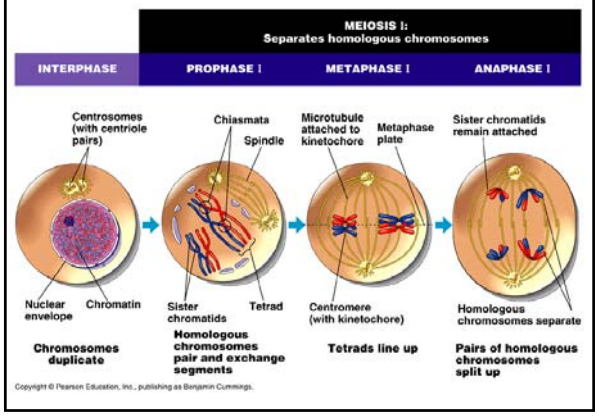


Cytokinesis separates the cytoplasm.

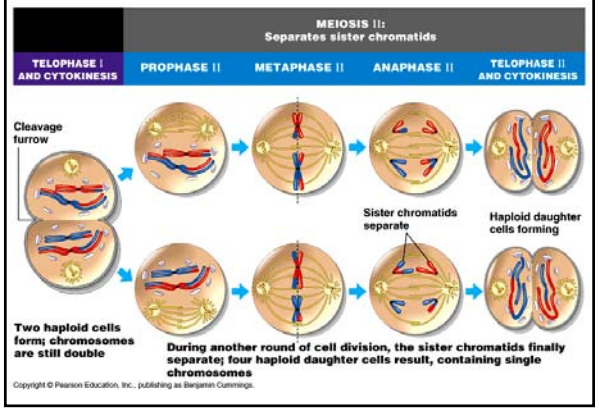
At the end of meiosis, there are four haploid daughter cells.



The stages of meiotic cell division: Meiosis I

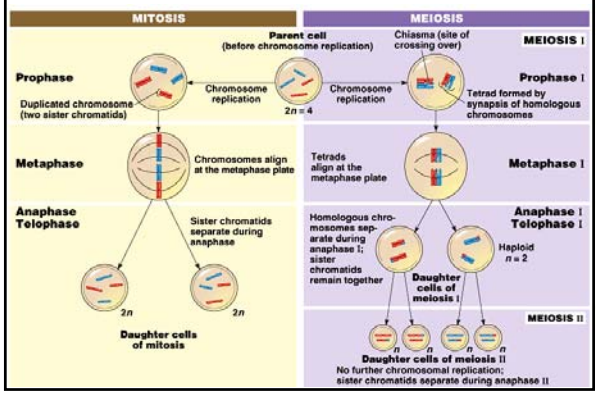


The stages of meiotic cell division: Meiosis II



- Mitosis and meiosis have several key differences.
  - The chromosome number is reduced by half in meiosis, but not in mitosis.
  - Mitosis produces daughter cells that are genetically identical to the parent and to each other.
  - Meiosis produces cells that differ from the parent and each other.

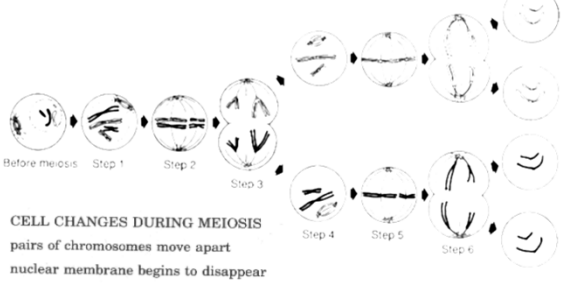
Mitosis produces two identical daughter cells, but meiosis produces 4 very different cells.



A comparison of mitosis and meiosis

SUMMARY

Event	Mitosis	Meiosis
DNA replication	Occurs during interphase before nuclear division begins	Occurs once, during the interphase before meiosis I begins
Number of divisions	One, including prophase, metaphase, anaphase, and telophase	Two, each including prophase, metaphase, anaphase, and telophase
Synapsis of homologous chromosomes	Does not occur	Synapsis is unique to meiosis: During prophase I, the homologous chromosomes join along their length, forming tetrads (groups of four chromatids); synapsis is associated with crossing over between nonsister chromatids
Number of daughter cells and genetic composition	Two, each diploid ($2n$) and genetically identical to the parent cell	Four, each haploid (n), containing half as many chromosomes as the parent cell; genetically nonidentical to the parent cell and to each other
Role in the animal body	Enables multicellular adult to arise from zygote; produces cells for growth and tissue repair	Produces gametes; reduces chromosome number by half and introduces genetic variability among the gametes



CELL CHANGES DURING MEIOSIS

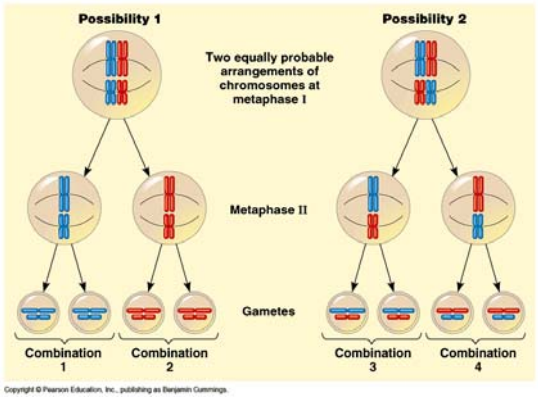
1 pairs of chromosomes move apart
1 nuclear membrane begins to disappear
1 four chromosomes present
1 cell starts to divide
1 sister chromatids move apart
7 four sex cells each with two chromosomes
5 two cells with two chromosomes
1/2 centrioles move to opposite sides

Sexual life cycles produce genetic variation among offspring

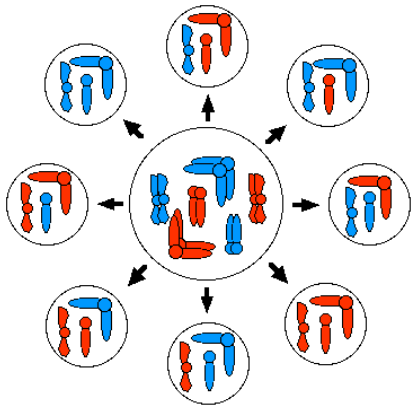
- The behavior of chromosomes during meiosis and fertilization is responsible for most of the variation that arises each generation during sexual reproduction.
- Three mechanisms contribute to genetic variation:
  - independent assortment
  - crossing over
  - random fertilization

- Independent assortment of chromosomes contributes to genetic variability due to the random orientation of tetrads at the metaphase plate.
  - There is a fifty-fifty chance that a particular daughter cell of meiosis I will get the maternal chromosome of a certain homologous pair and a fifty-fifty chance that it will receive the paternal chromosome.

The results of alternative arrangements of two chromosome pairs



- Each homologous pair of chromosomes is positioned independently of the other pairs at metaphase I.
- Therefore, the first meiotic division results in independent assortment of maternal and paternal chromosomes into daughter cells.
- The number of combinations possible when chromosomes assort independently into gametes is 2^n, where *n* is the haploid number of the organism.
  - If n = 3, there are eight possible combinations.
  - For humans with n = 23, there are 2^{23} or about 8 million possible combinations of chromosomes.

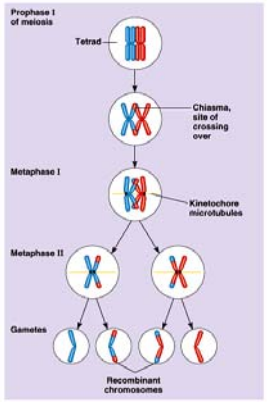


Independent Assortment

In addition to Crossing-Over, the process of meiosis ensures that chromosomes are randomly assorted. The following images show a cell where the chromosome number = 3.

Notice all of the possible combinations.

- Independent assortment alone would find each individual chromosome in a gamete that would be exclusively maternal or paternal in origin.
- However, **crossing over** produces **recombinant chromosomes,** which combine genes inherited from each parent.

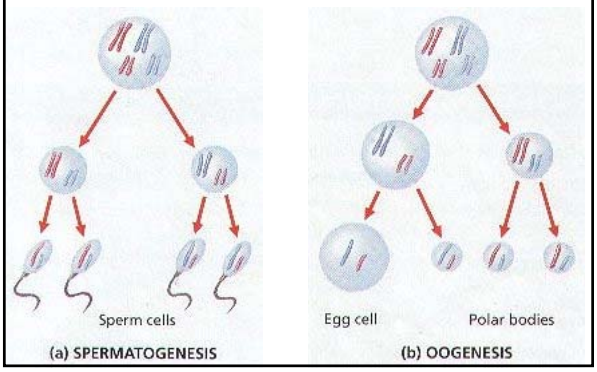


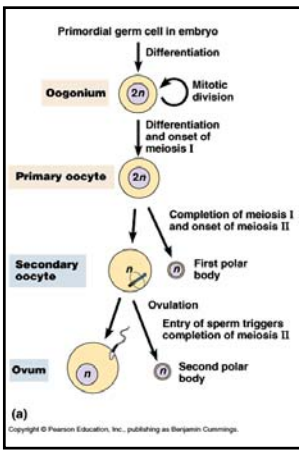
- Crossing over begins very early in prophase I as homologous chromosomes pair up gene by gene.
- In crossing over, homologous portions of two nonsister chromatids trade places.
  - For humans, this occurs two to three times per chromosome pair.
- One sister chromatid may undergo different patterns of crossing over than its match.
- Independent assortment of these nonidentical sister chromatids during meiosis II increases still more the number of genetic types of gametes that can result from meiosis.

- The random nature of fertilization adds to the genetic variation arising from meiosis.
- Any sperm can fuse with any egg.
  - A zygote produced by a mating of a woman and man has a unique genetic identity.
  - An ovum is one of approximately 8 million possible chromosome combinations (actually 2^{23}).
  - The successful sperm represents one of 8 million different possibilities (actually 2^{23}).
  - The resulting zygote is composed of 1 in 70 trillion (2^{23} x 2^{23}) possible combinations of chromosomes.
  - Crossing over adds even more variation to this.

- The three sources of genetic variability in a sexually reproducing organism are:
  - Independent assortment of homologous chromosomes during meiosis I and of nonidentical sister chromatids during meiosis II.
  - Crossing over between homologous chromosomes during prophase I.
  - Random fertilization of an ovum by a sperm.
- All three mechanisms reshuffle the various genes carried by individual members of a population.
- On top of these three sources of variation there are Mutations which are ultimately what create the majority of a population's diversity of genes.

Meiosis in Humans





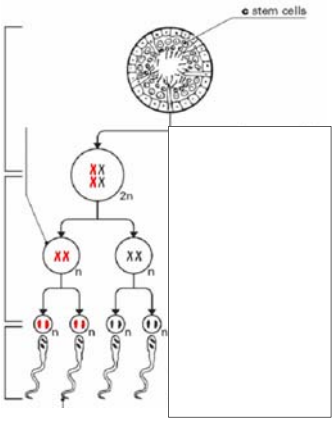
Oogenesis

Oogenesisis the formation of a female gamete, called an ovum (egg).

Unlike the production of sperm Oogenesisis starts before birth but pauses at prophase 1. Once the females reaches puberty meiosis is completed once cell at a time as part of a cyclical process called estrus.

Each cycle (which includes the completion of meiosis II) lasts about 28 days and is repeated throughout a woman's reproductive years.

Polar bodies are created by disproportionate cytokinesis



Spermatogenesis

The process by which male gametes (sex cells), or sperm, are formed is known as spermatogenesis.

It involves meiosis (the type of cell division that produces gametes). Each cell that begins the process will result in 4 sperm cells.

It begins in young men around the age of 14 and continues throughout life.

It takes a few weeks for each gamete to be formed and reach maturity.