

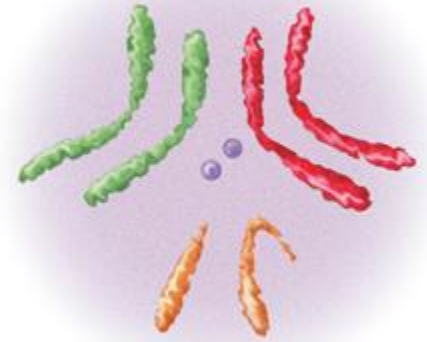
Meiosis Notes

THINK ABOUT IT

As geneticists in the early 1900s applied Mendel's laws, they wondered where genes might be located.


They expected genes to be carried on structures inside the cell, but *which* structures?

What cellular processes could account for segregation and independent assortment, as Mendel had described?



Chromosome Number

 How many sets of genes do multicellular organisms inherit?

 **The diploid cells of most adult organisms contain two complete sets of inherited chromosomes and two complete sets of genes.**

What are Chromosomes?

Chromosomes—those strands of DNA and protein inside the cell nucleus—are the carriers of genes.

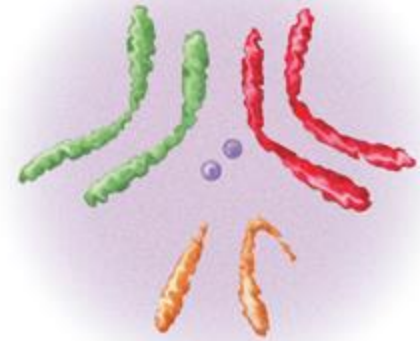
The genes are located in specific positions on chromosomes.

What are Diploid Cells

A body cell in an adult fruit fly has eight chromosomes, as shown in the figure.

Four of the chromosomes come from its male parent, and four come from its female parent.

These two sets of chromosomes are **homologous**, meaning that each of the four chromosomes from the male parent has a corresponding chromosome from the female parent.



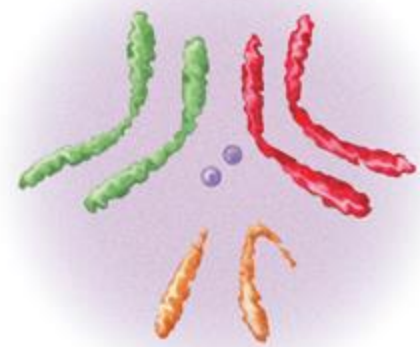
What are Diploid Cells?

A cell that contains both sets of homologous chromosomes is **diploid**, meaning “two sets.”

The diploid number of chromosomes is sometimes represented by the symbol **2N**.

For the fruit fly, the diploid number is 8, which can be written as $2N = 8$, where N represents twice the number of chromosomes in a sperm or egg cell.

These two sets of chromosomes are **homologous**, meaning that each of the four chromosomes from the male parent has a corresponding chromosome from the female parent



What are Haploid Cells

Some cells contain only a single set of chromosomes, and therefore a single set of genes.

Such cells are **haploid**, meaning “one set.”

The gametes of sexually reproducing organisms are haploid.

For fruit fly gametes, the haploid number is 4, which can be written as $N = 4$.




What is Meiosis?

Meiosis is a process in which the number of chromosomes per cell is cut in half through the separation of homologous chromosomes in a diploid cell.




Meiosis usually involves two distinct divisions, called meiosis I and meiosis II.

By the end of meiosis II, the diploid cell becomes four haploid cells.




Phases of Meiosis

-  What events occur during each phase of meiosis?
-  In prophase I of meiosis, each replicated chromosome pairs with its corresponding homologous chromosome.
-  During metaphase I of meiosis, paired homologous chromosomes line up across the center of the cell.

Phases of Meiosis

-  What events occur during each phase of meiosis?
-  As the cells enter prophase II, their chromosomes—each consisting of two chromatids—become visible.
-  The final four phases of meiosis II are similar to those in meiosis I. However, the result is four haploid daughter cells.

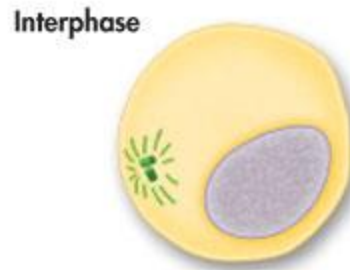
Phases of Meiosis

-  What events occur during each phase of meiosis?
-  During anaphase I, spindle fibers pull each homologous chromosome pair toward opposite ends of the cell.
-  In telophase I, a nuclear membrane forms around each cluster of chromosomes. Cytokinesis follows telophase I, forming two new cells.

Meiosis I

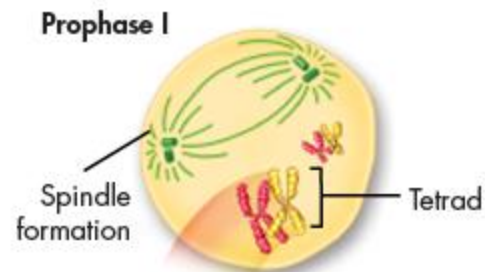
Just prior to meiosis I, the cell undergoes a round of chromosome replication called interphase I.

Each replicated chromosome consists of two identical chromatids joined at the center.



Prophase I

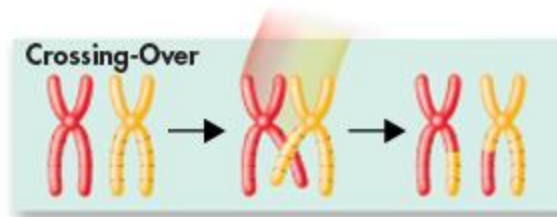
The cells begin to divide, and the chromosomes pair up, forming a structure called a **tetrad**, which contains four chromatids.



Prophase I

As homologous chromosomes pair up and form tetrads, they undergo a process called **crossing-over**.

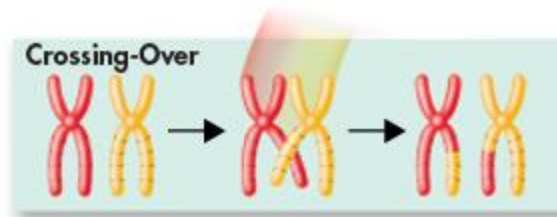
First, the chromatids of the homologous chromosomes cross over one another.



Prophase I

Then, the crossed sections of the chromatids are exchanged.

Crossing-over is important because it produces new combinations of alleles in the cell.



Metaphase I and Anaphase I

As prophase I ends, a spindle forms and attaches to each tetrad.

During metaphase I of meiosis, paired homologous chromosomes line up across the center of the cell.

Metaphase I



Metaphase I and Anaphase I

During anaphase I, spindle fibers pull each homologous chromosome pair toward opposite ends of the cell.

When anaphase I is complete, the separated chromosomes cluster at opposite ends of the cell.

Anaphase I



Telophase I and Cytokinesis

During telophase I, a nuclear membrane forms around each cluster of chromosomes.

Cytokinesis follows telophase I, forming two new cells.

Telophase I
and Cytokinesis



Meiosis I

Meiosis I results in two cells, called daughter cells, each of which has four chromatids, as it would after mitosis.

Because each pair of homologous chromosomes was separated, neither daughter cell has the two complete sets of chromosomes that it would have in a diploid cell.

The two cells produced by meiosis I have sets of chromosomes and alleles that are different from each other and from the diploid cell that entered meiosis I.



Meiosis II

The two cells produced by meiosis I now enter a second meiotic division.

Unlike the first division, neither cell goes through a round of chromosome replication before entering meiosis II.



Prophase II

As the cells enter prophase II, their chromosomes—each consisting of two chromatids—become visible.

The chromosomes do not pair to form tetrads, because the homologous pairs were already separated during meiosis I.



Metaphase II

During metaphase of meiosis II, chromosomes line up in the center of each cell.

Metaphase II



Anaphase II

As the cell enters anaphase, the paired chromatids separate.



Telophase II, and Cytokinesis

In the example shown here, each of the four daughter cells produced in meiosis II receives two chromatids.

Telophase II
and Cytokinesis



Telophase II, and Cytokinesis

These four daughter cells now contain the haploid number (N)—just two chromosomes each.

Telophase II
and Cytokinesis



Gametes to Zygotes

The haploid cells produced by meiosis II are gametes.

In male animals, these gametes are called sperm. In some plants, pollen grains contain haploid sperm cells.

In female animals, generally only one of the cells produced by meiosis is involved in reproduction. The female gamete is called an egg in animals and an egg cell in some plants.

How do Gametes Become Zygotes

Fertilization—the fusion of male and female gametes—generates new combinations of alleles in a **zygote**.

The zygote undergoes cell division by mitosis and eventually forms a new organism.

How is meiosis different from mitosis?

In mitosis, when the two sets of genetic material separate, each daughter cell receives one complete set of chromosomes. In meiosis, homologous chromosomes line up and then move to separate daughter cells.

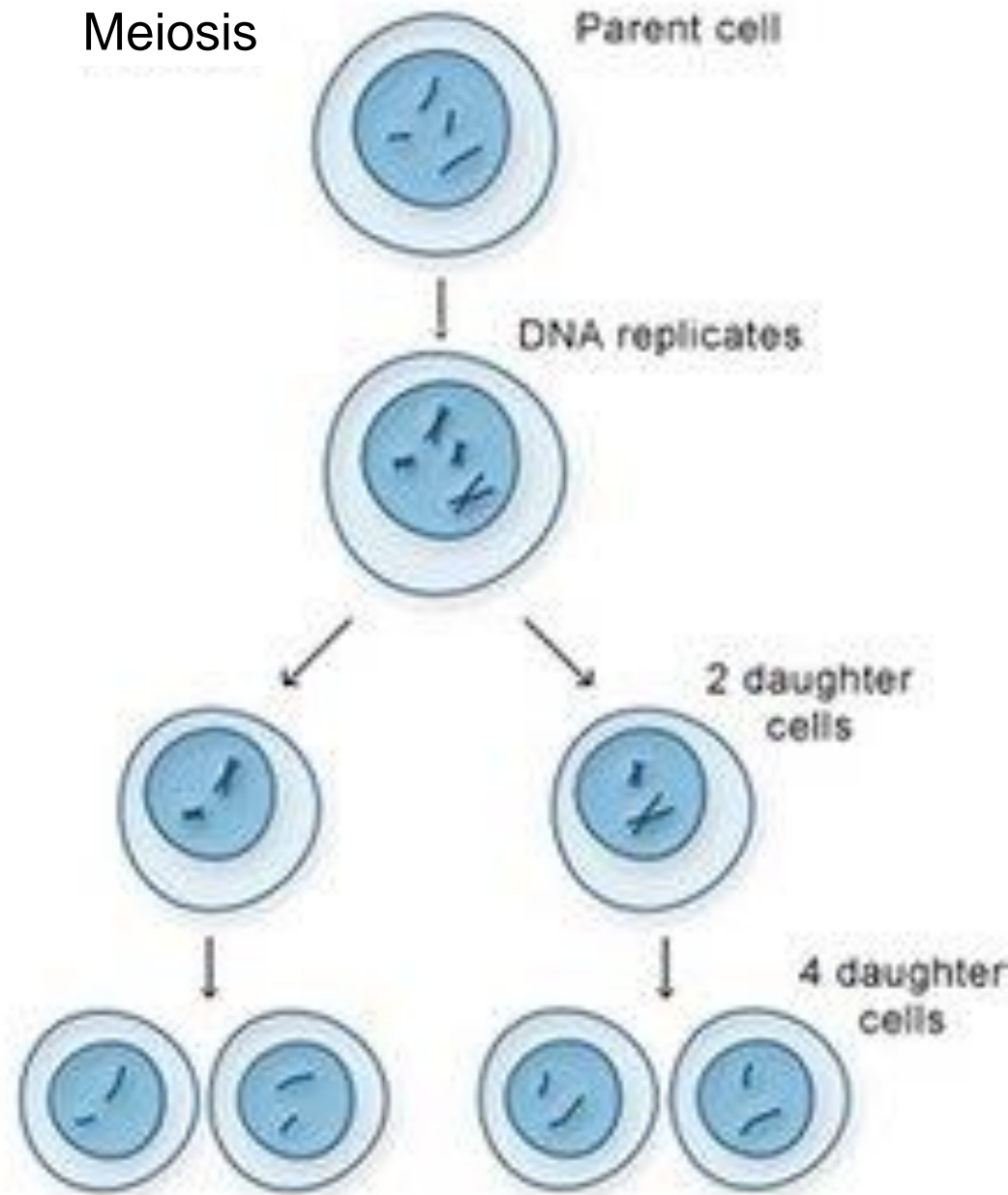
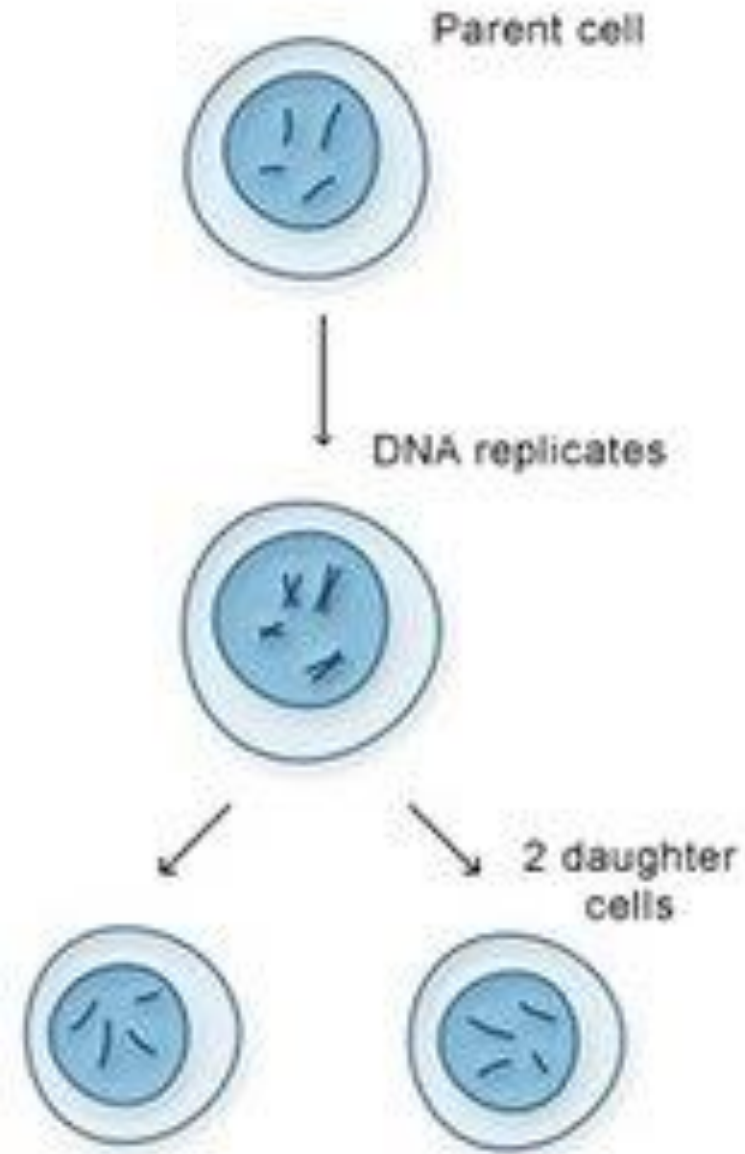
Mitosis does not normally change the chromosome number of the original cell. This is not the case for meiosis, which reduces the chromosome number by half.

Mitosis results in the production of two genetically identical diploid cells, whereas meiosis produces four genetically different haploid cells.

Mitosis is a form of asexual reproduction, whereas meiosis is an early step in sexual reproduction.

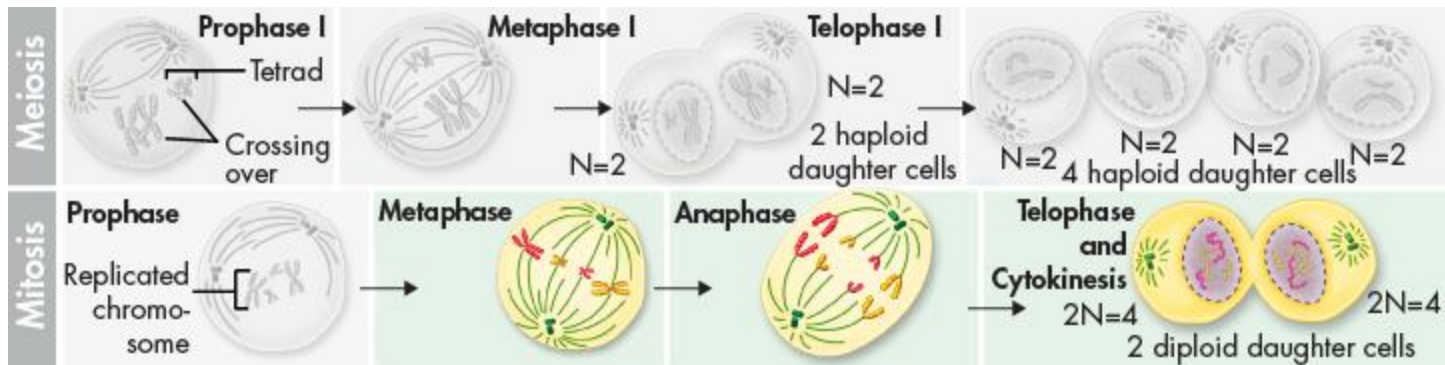
Mitosis

Meiosis



Replication and Separation of Genetic Material

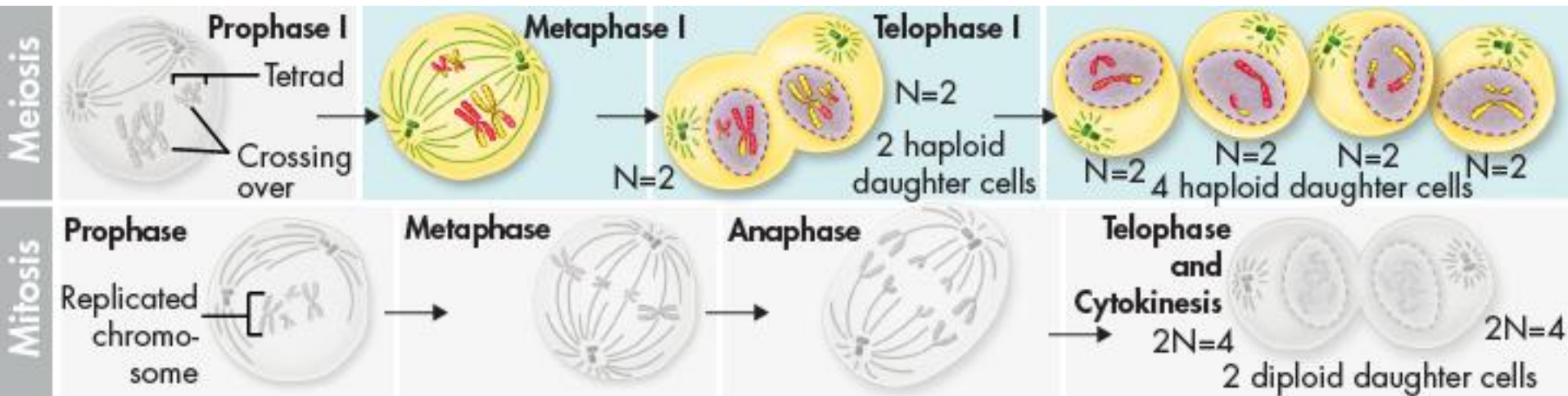
In mitosis, when the two sets of genetic material separate, each daughter cell receives one complete set of chromosomes.



Replication and Separation of Genetic Material

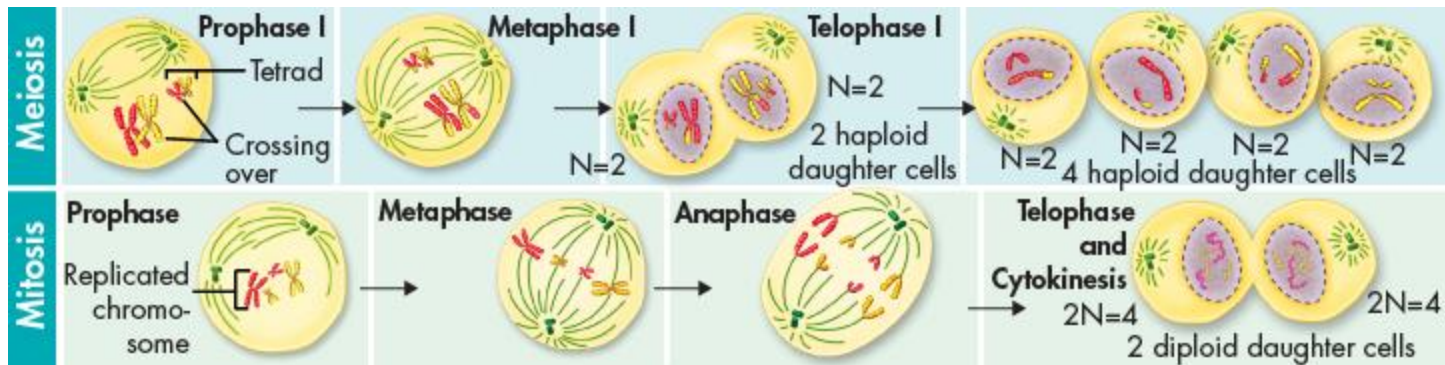
In meiosis, homologous chromosomes line up and then move to separate daughter cells.

As a result, the two alleles for each gene segregate from each other and end up in different cells.



Replication and Separation of Genetic Material

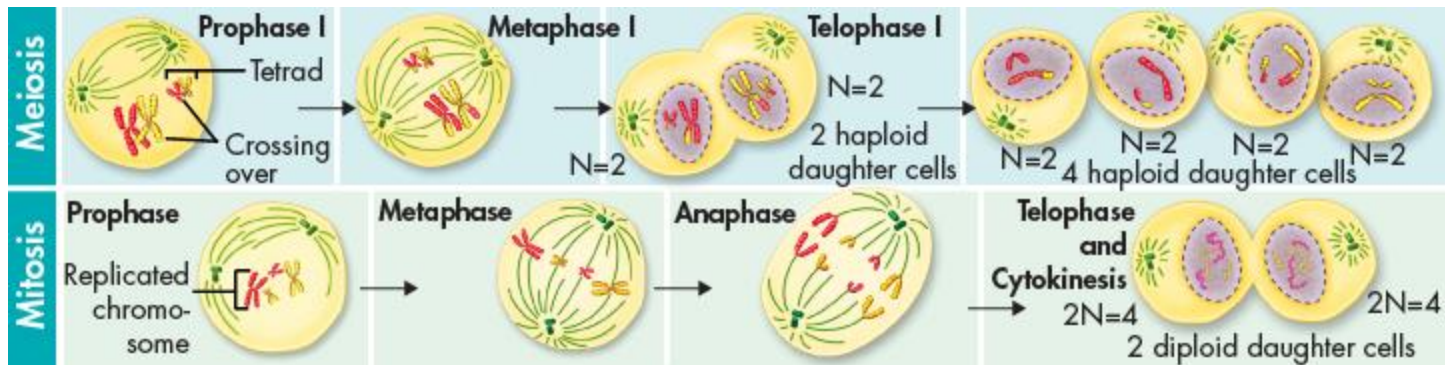
The sorting and recombination of genes in meiosis result in a greater variety of possible gene combinations than could result from mitosis.



Changes in Chromosome Number

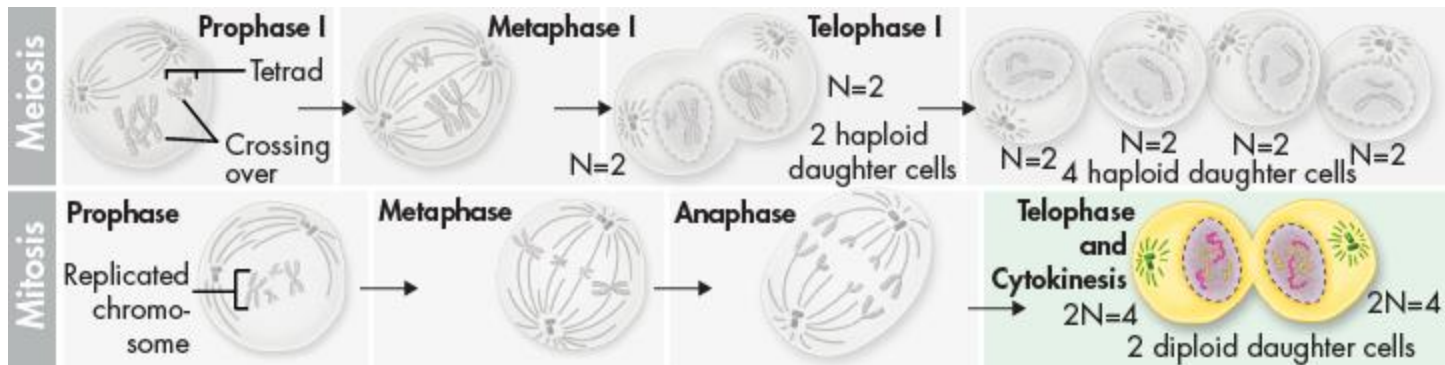
Mitosis does not normally change the chromosome number of the original cell.

Meiosis reduces the chromosome number by half.



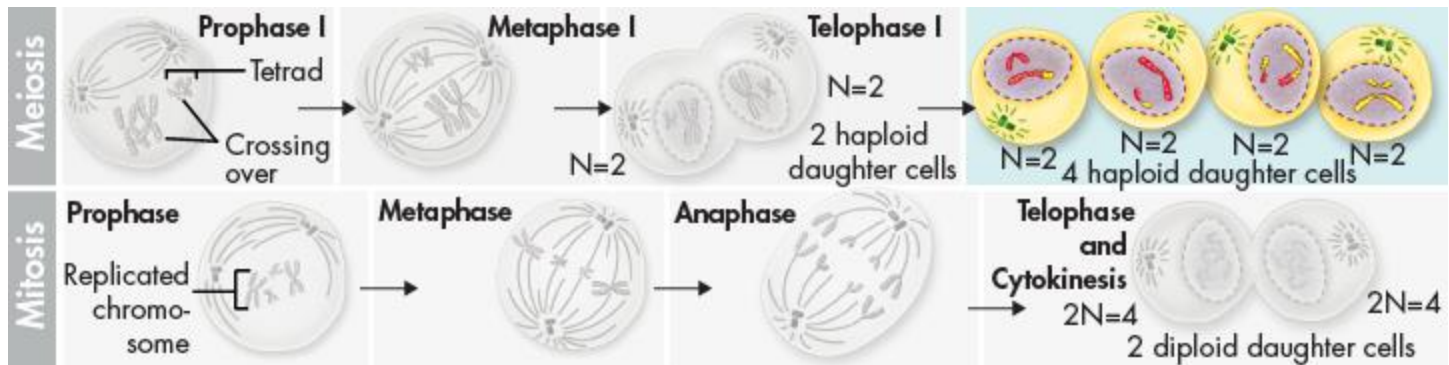
Changes in Chromosome Number

A diploid cell that enters mitosis with eight chromosomes will divide to produce two diploid daughter cells, each of which also has eight chromosomes.



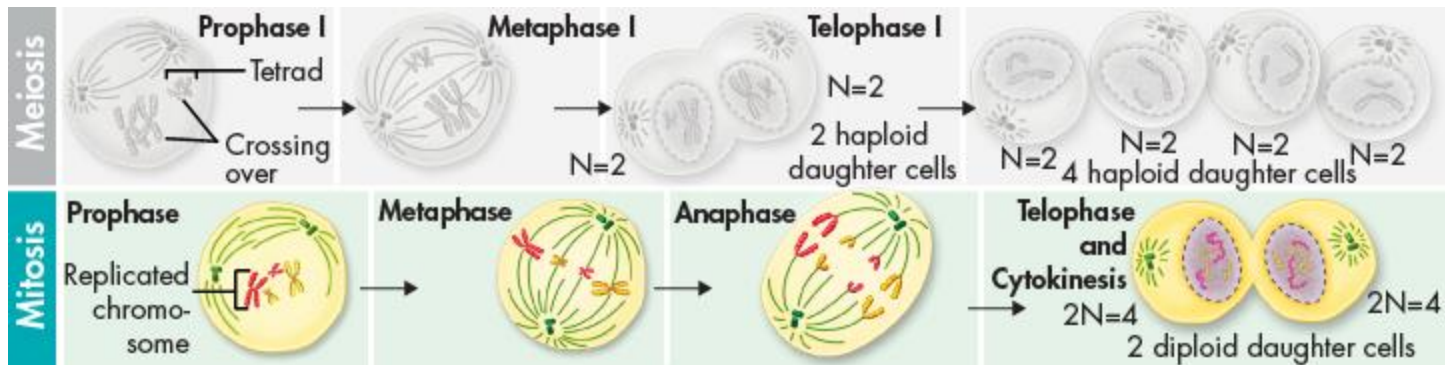
Changes in Chromosome Number

On the other hand, a diploid cell that enters meiosis with eight four chromosomes will pass through two meiotic divisions to produce four haploid gamete cells, each with only four two chromosomes.



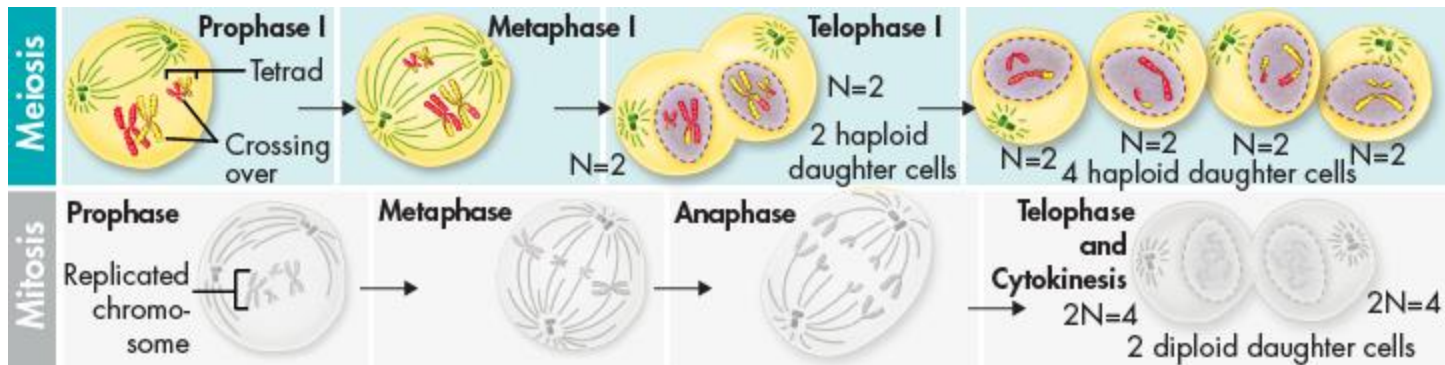
Number of Cell Divisions

Mitosis is a single cell division, resulting in the production of two genetically identical diploid daughter cells.



Number of Cell Divisions

Meiosis requires two rounds of cell division, and, in most organisms, produces a total of four genetically different haploid daughter cells.



Gene Linkage and Gene Maps

 How can two alleles from different genes be inherited together?

Gene Linkage and Gene Maps



How can two alleles from different genes be inherited together?



Alleles of different genes tend to be inherited together from one generation to the next when those genes are located on the same chromosome.

Gene Linkage

Thomas Hunt Morgan's research on fruit flies led him to the principle of gene linkage.

After identifying more than 50 *Drosophila* (fruit fly) genes, Morgan discovered that many of them appeared to be “linked” together in ways that seemed to violate the principle of independent assortment.

Gene Linkage

For example, Morgan used a fly with reddish-orange eyes and miniature wings in a series of test crosses.

His results showed that the genes for those two traits were almost always inherited together.

Only rarely did the genes separate from each other.

Gene Linkage

Morgan and his associates observed so many genes that were inherited together that, before long, they could group all of the fly's genes into four linkage groups.

The linkage groups assorted independently, but all of the genes in one group were inherited together.

As it turns out, *Drosophila* has four linkage groups and four pairs of chromosomes.

Gene Linkage

Morgan's findings led to two remarkable conclusions:

First, each chromosome is actually a group of linked genes.

Second, it is the chromosomes that assort independently, not individual genes.

Alleles of different genes tend to be inherited together when those genes are located on the same chromosome.

Gene Mapping

In 1911, Columbia University student Alfred Sturtevant wondered if the frequency of crossing-over between genes during meiosis might be a clue to the genes' locations.

Sturtevant reasoned that the farther apart two genes were on a chromosome, the more likely it would be that a crossover event would occur between them.

If two genes are close together, then crossovers between them should be rare. If two genes are far apart, then crossovers between them should be more common.

Gene Mapping

By this reasoning, he could use the frequency of crossing-over between genes to determine their distances from each other.

Sturtevant gathered lab data and presented a gene map showing the relative locations of each known gene on one of the *Drosophila* chromosomes.

Sturtevant's method has been used to construct gene maps ever since this discovery.

