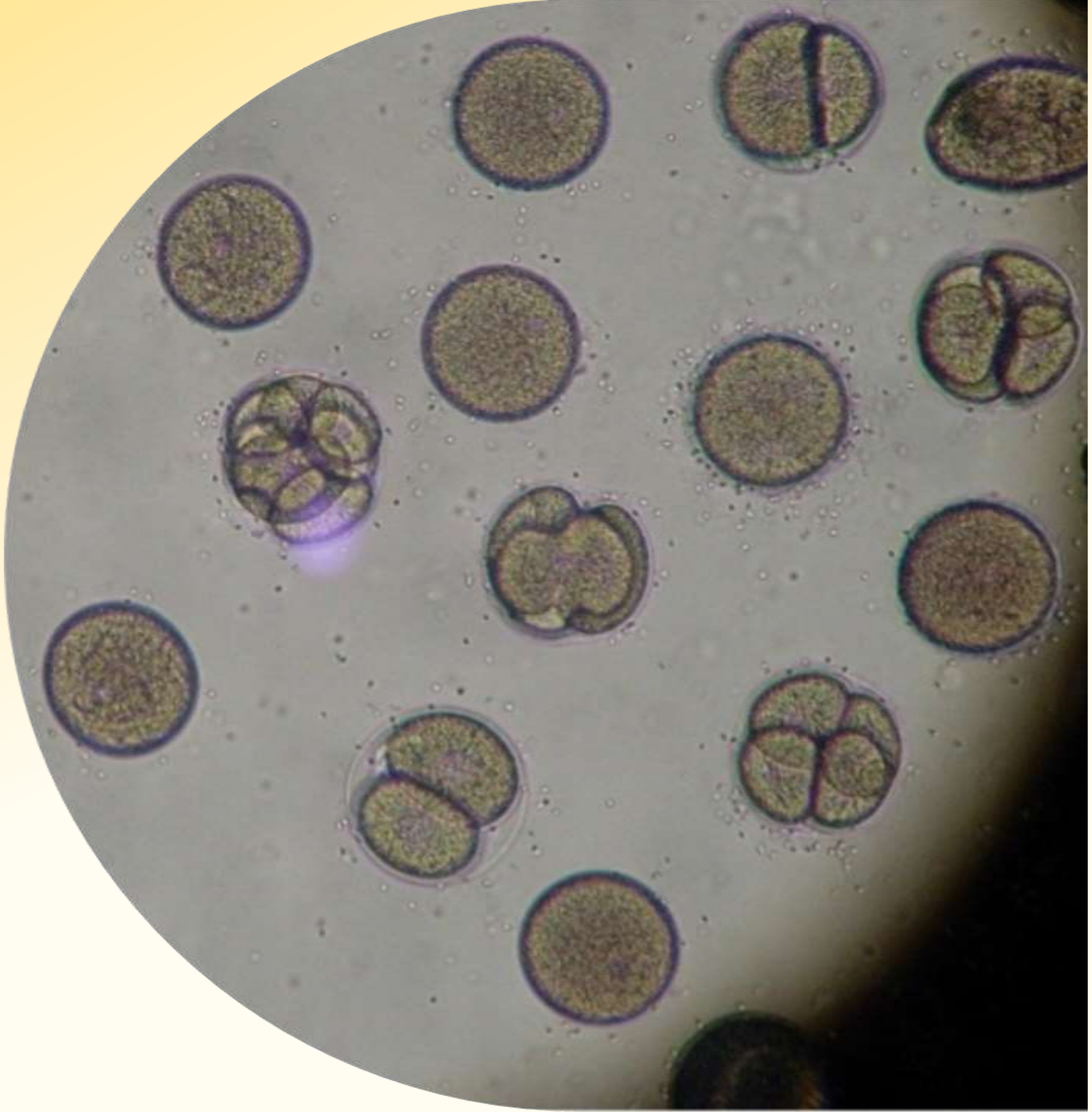
WUHS Biology: Traits & Genes Unit

Week 2 – How are traits inherited from parents?



Traits & Genes Unit – W2 Driving Questions

- **Driving Question: How are traits inherited from parents?**
- How do organisms of a species reproduce?
- How does reproduction affect diversity and species survival?
- How do reproductive cells (like sperm and egg cells) form?
- Why do offspring look similar but not identical to their parents?

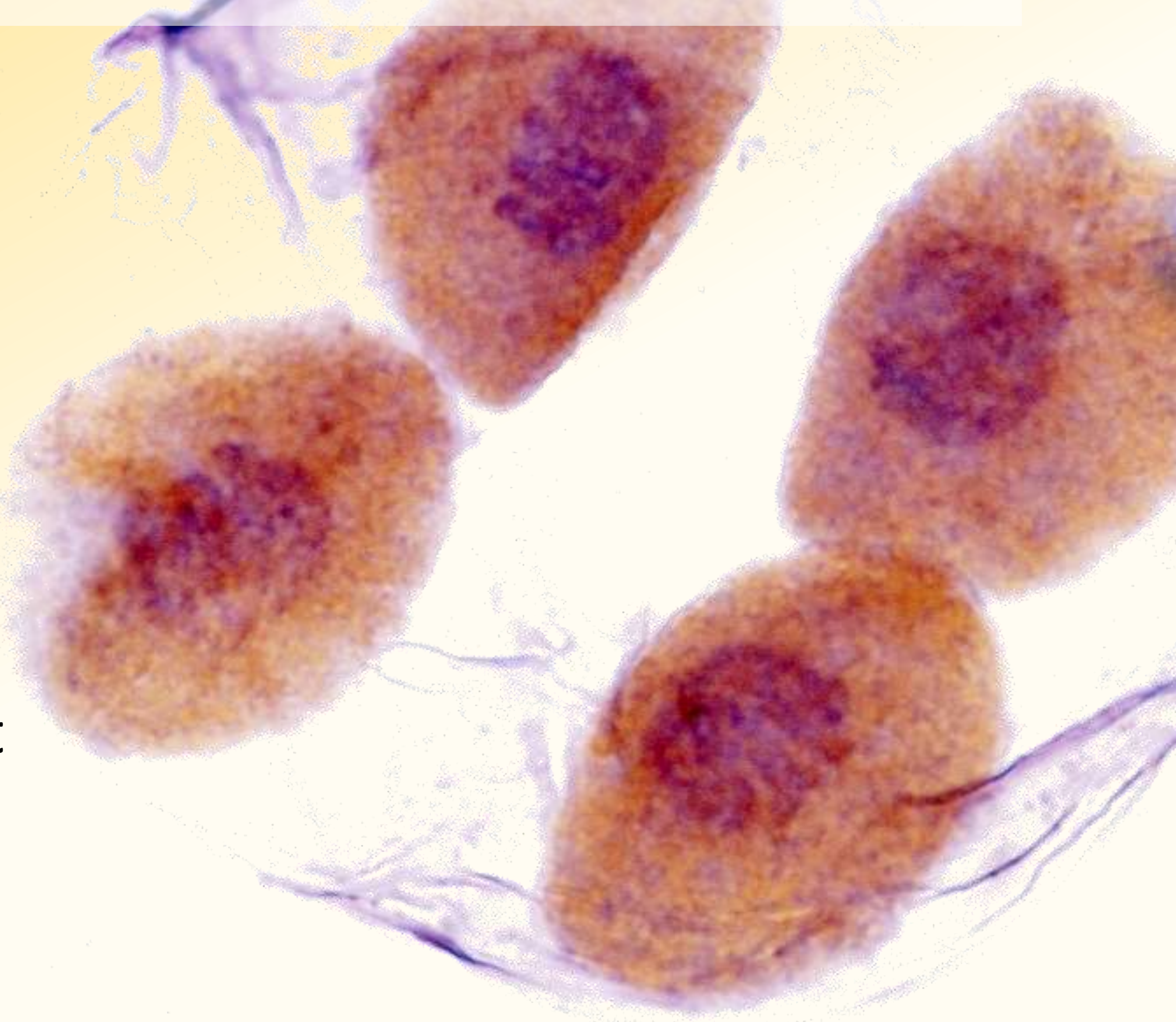


Image Source: [Wikimedia]

Recap of Week 1

An organism's traits are determined by the kinds of proteins assembled in its cells.

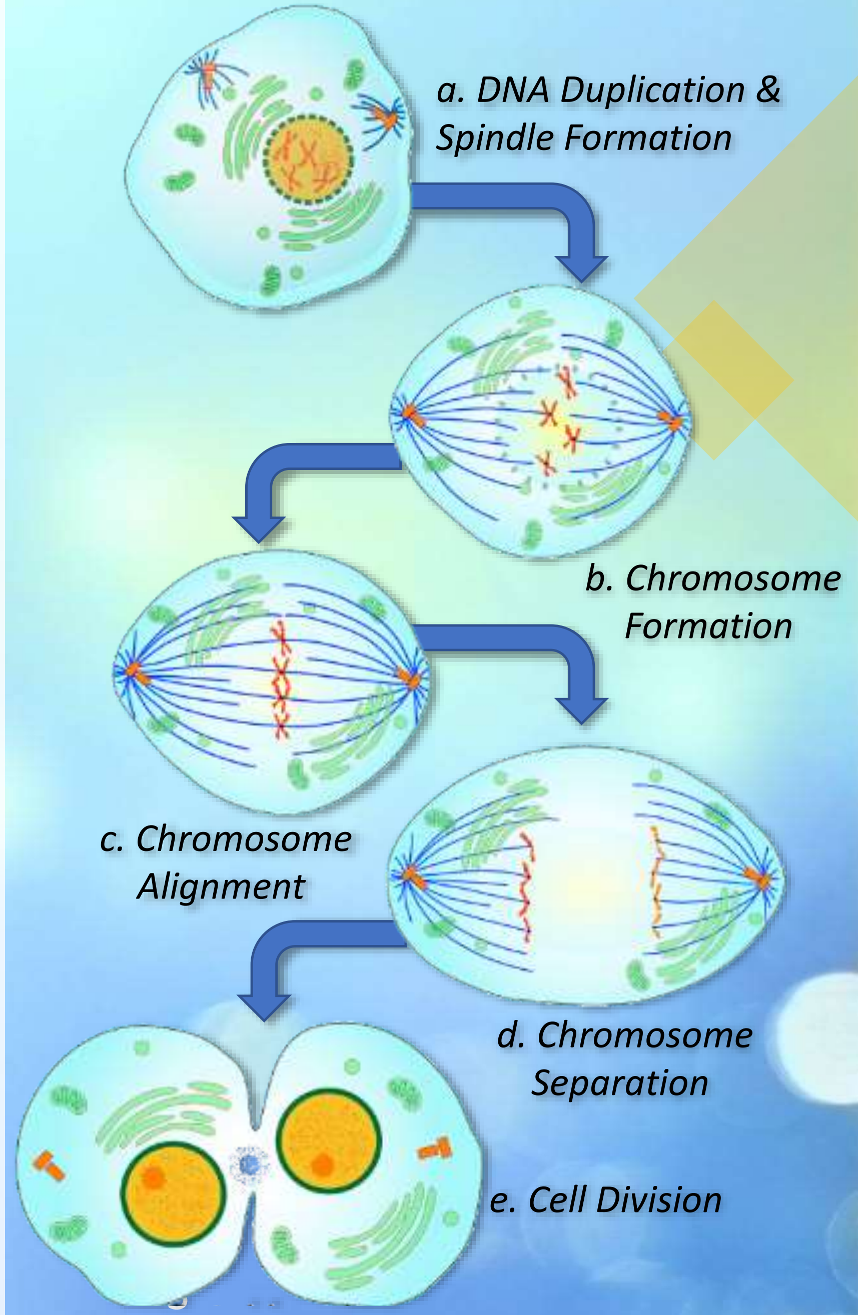
The instructions for assembling a protein are in DNA.

A gene is a section of DNA that contains the instructions for the assembly of a particular protein.

DNA can be coiled into tight packages called chromosomes prior to mitosis to ensure that it is divided evenly between each cell.

Mitosis consists of a few key steps, including…
a) duplicating DNA and assembling spindle proteins;
b) packing DNA into chromosomes using histones;
c) lining duplicated chromosomes onto spindles;
d) separating the chromosome copies; and
e) dividing the cell in half.

Image Source: Wikimedia



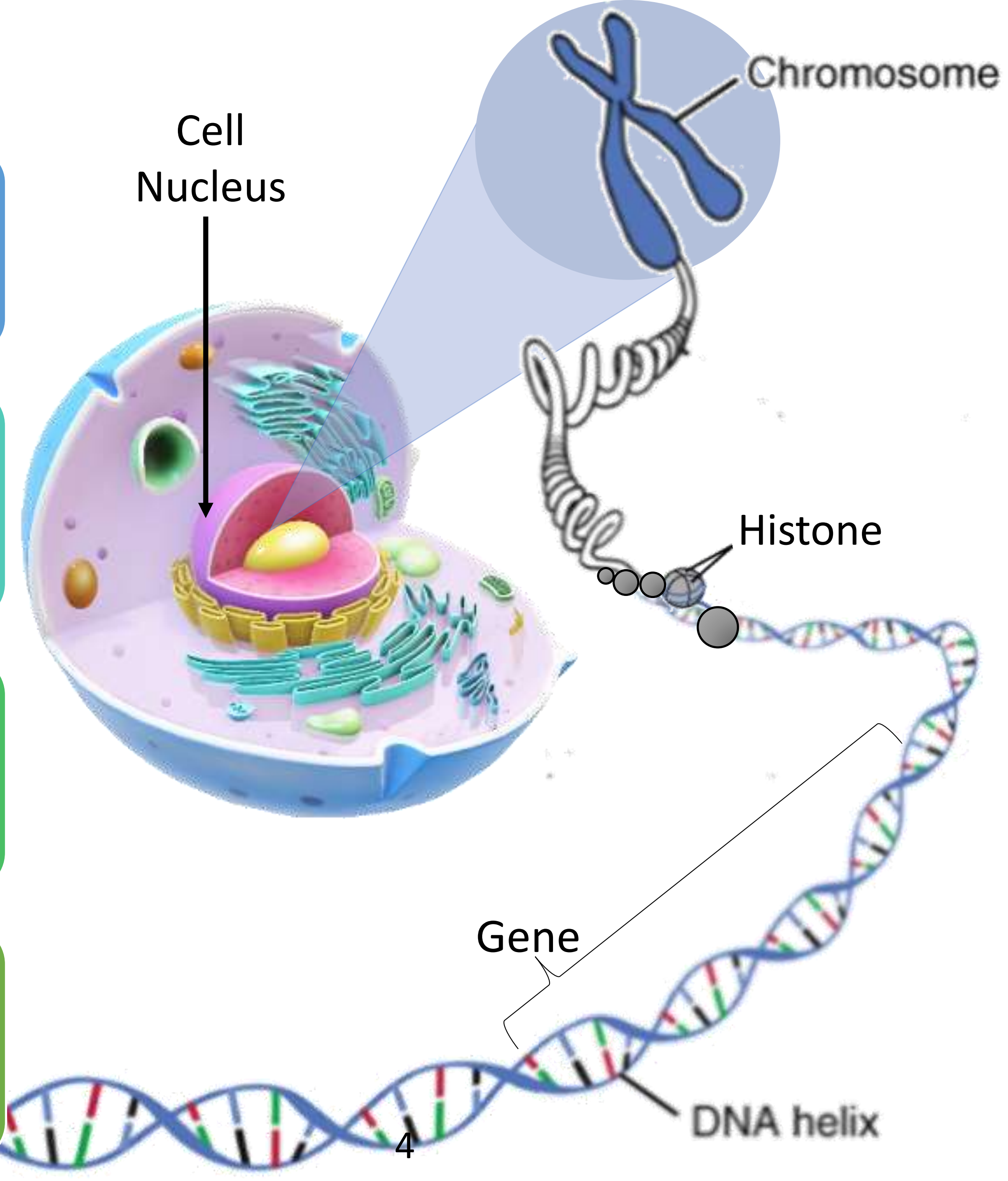
Recap of Week 1

Cell division must be carefully regulated. Slow cell division limits growth and healing. Overly-rapid cell division can result in cancer.

Regulator proteins like *cyclin* (which stimulates *spindle* formation) and *growth factors* limit when and how often a cell can divide.

Exponential growth explains how trillions of cells can form from just one. In only 40 cycles of doubling, one cell can become trillions.

Through cellular differentiation, cells receive signals to turn off some genes, which determines a cell's eventual function.



Variation Among Individuals

- **Last week we learned that cells duplicate their DNA prior to mitosis.**
  - This ensures that each cell receives a copy of the instructions needed for assembling proteins.
- **Differences between species and among individuals are due to differences in how cells assemble proteins.**
  - Different genes result in the production of different proteins, resulting in different traits.
- **Where does the first cell of an organism come from?**
  - If trillions of cells can come from one cell, where does that first cell originate?
- **Where do the differences in each organism's genes come from?**
  - If DNA is duplicated during mitosis, why aren't all cells the same?

Image Source: Wikimedia

Asexual Reproduction

- **Organisms can reproduce themselves in multiple ways.**
  - Some species replicate themselves via asexual reproduction, producing a genetically identical copy of itself.
  - For example, reproduction in single-celled bacteria can be very similar to mitosis – they enlarge their cells, duplicate their DNA, and divide.
  - This process tends to enable rapid reproduction. Bacteria can double their populations in less than five minutes.
- **Many plants can also utilize asexual reproduction.**
  - Most fruit in grocery stores is produced by taking a cuttings from existing trees and grafting them on to trunks of other trees.
    - *This ensures that farmers can produce the exact same kinds of fruit year after year to meet consumers' expectations.*
  - Asexual reproduction can also occur naturally in many plants. For example, plants with thick roots and stems (such as potatoes, tulips, garlic, and strawberries) can often duplicate asexually.

Image Source: Wikimedia

Bacterial asexual reproduction results in identical cells.

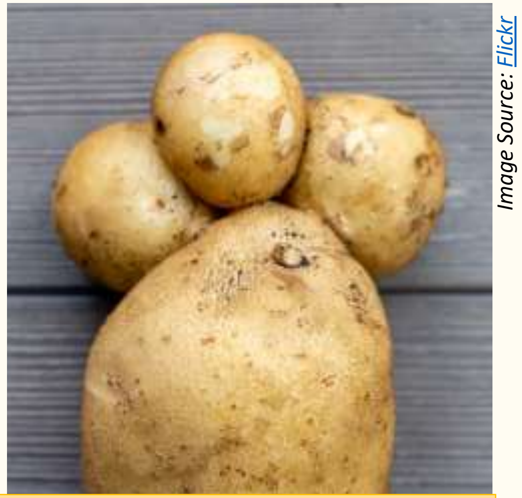


Image Source: Flickr

Some plants, like these potatoes, can reproduce asexually.

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Sexual Reproduction

- **<u>Sexual reproduction</u> results in offspring that have a mixture of traits from their parents.**
  - Most animals and plants reproduce through sexual reproduction.
- **The primary advantage of sexual reproduction is that it increases the genetic diversity of organisms within a species.**
  - A greater amount of genetic diversity improves the capacity of organisms in a species to adapt to changes in their environment.
  - This increases the resiliency of a species to disturbances.
  - The lower the genetic diversity, the greater the risk of widespread loss of individuals within a species due to threats like disease.

Genetic diversity within species like these tree frogs increases their ability to adapt and respond to changes.

Image Source; U. Maine Extension

Irish Potato Famine

- **The Irish Potato Famine of the mid-1800s provides a stark example of the risks of reduced genetic diversity.**
  - In the early 1800s, the Ireland's population grew rapidly, straining food supplies.
  - A variety of potato (the "lumper") provided a quick and easy supply of food.
- **Soon, most potatoes grown in Ireland were genetically identical versions of the "lumper".**
  - Lumpers were all susceptible a pathogen called *Phytophthora infestans,* which spread rapidly through the country in the early 1840s.
  - When infected, it decomposed lumper potatoes into inedible slime.
  - Ultimately, over a million people died of starvation in only 3 years.
- **Limited genetic diversity remains prevalent today.**
  - Wheat, rice, and corn alone provide over 50% of the world's plant-based calories.

Image Source: Wikimedia

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Reproductive Cells

- **Sexual reproduction increases the amount of genetic diversity.**
  - For sexual reproduction to occur, the organisms of that species must be able to produce cells that each have half the amount of genetic material. These cells are called gametes.
  - For example, animals produce sperm and egg cells, each with half the number of chromosome.
    - *In humans, gametes have 23 chromosomes, whereas the rest of the cells of the body typically have 46 chromosomes.*
- **Most plants also produce sperm and egg cells.**
  - Plant sperm cells are found within pollen grains in flowering plants. Egg cells are found within the ovules of flowers.
  - *Pollinators*, such as bees and butterflies, provide a way to bring the sperm cells from different plants to fertilize egg cells.

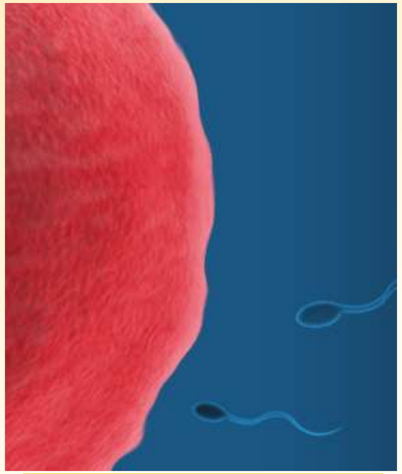

Image Source: Flickr

Animal gametes include sperm & egg cells.

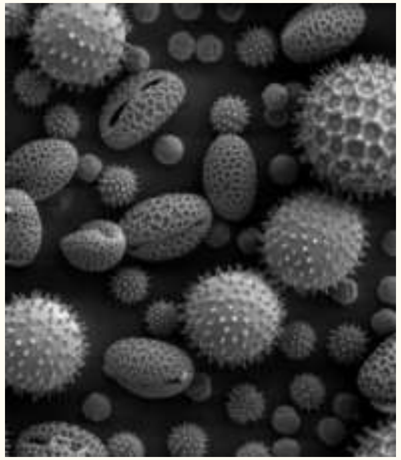

Image Source: Stockvault

Plant gametes are found in pollen (above) & flower ovules.

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Meiosis

- **The production of gametes (sperm and egg cells) requires reducing the amount of DNA in a cell.**
  - Typically, animal cells have two copies of each gene (diploid).
  - Sperm and egg cells only have one copy of each gene (haploid).
  - If gametes (sperm and egg cells) contained the same amount of DNA as the rest of the cells of the body, the amount of DNA in an organism would double every time it reproduced.

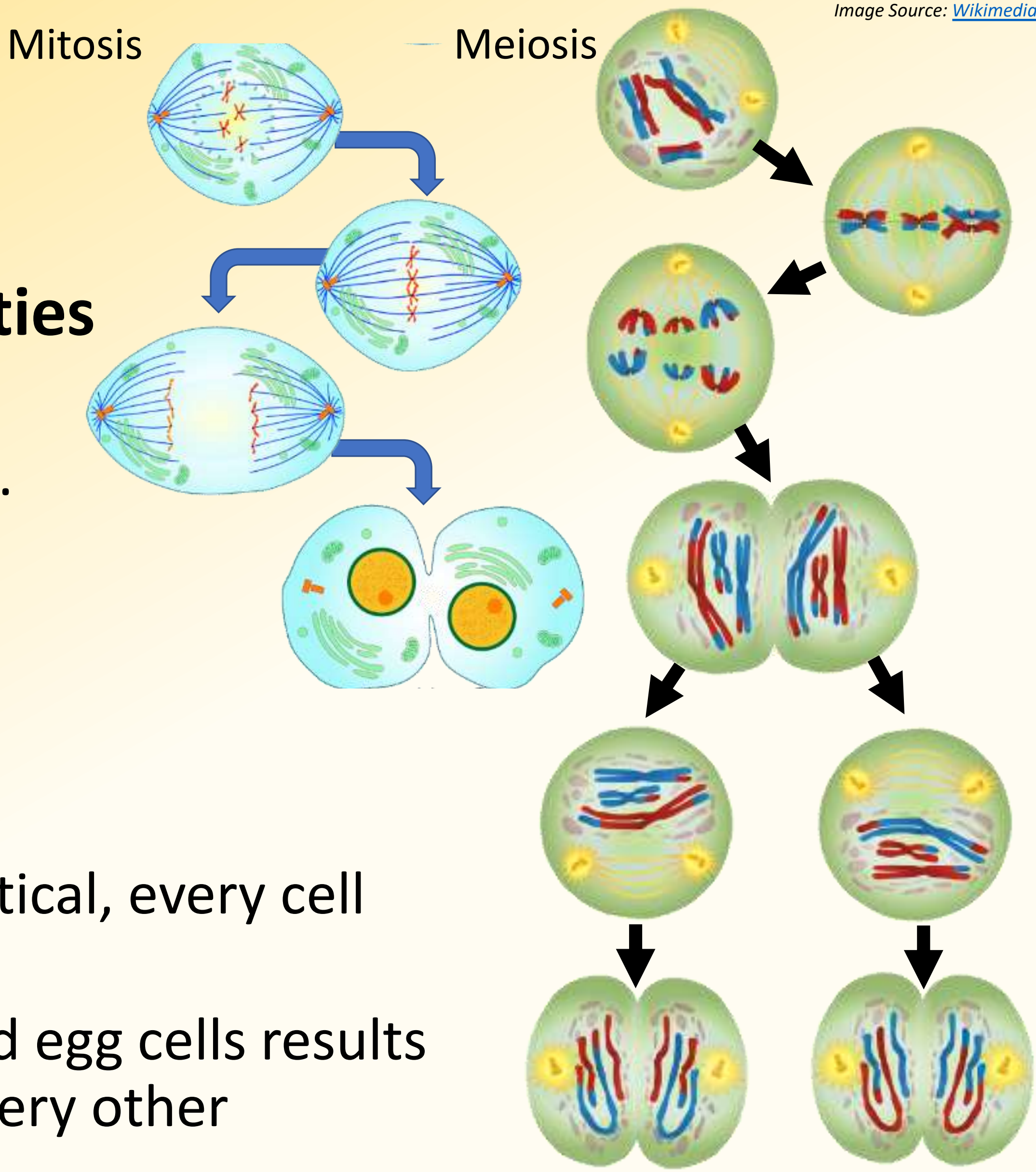
- **The process cell division that produces haploid gamete cells is called meiosis.**
  - Through meiosis, a bodily cell with two copies of each gene is changed into a sperm or egg cell with only one copy of each gene.

Image Source: Wikimedia

Image Source: Wikimedia

Process of Meiosis

- **The process of meiosis shares many similarities with mitosis (regular cell division).**
  - Both begin by replicating the DNA within the cell.
  - Both involve splitting a cell into two cells.
- **The key difference is that mitosis results in identical diploid cells, while meiosis results in genetically unique haploid cells.**
  - While each cell produced through mitosis is identical, every cell produced through meiosis is genetically unique.
  - The combination of genetically unique sperm and egg cells results in offspring that are genetically different from every other organism in their species*.



Mitosis (*left*) results in identical diploid cells.
Meiosis (*right*) results in unique haploid cells.

**Except for identical twins and clones.*

Process of Meiosis

- **Meiosis and mitosis both begin with similar steps.**
  - First, the DNA in each cell must be duplicated.
  - Then the DNA is condensed into chromosomes by histones.
  - Chromosomes are attached to spindle proteins.
  - Chromosome copies then move apart.
  - The cell divides in half, producing two cells.
- **In meiosis, a second round of cell division occurs.**
  - Unlike the first round, DNA is not duplicated.
  - After this second round of cell division, each of the resulting cells will have half the amount of DNA of a regular diploid cell.

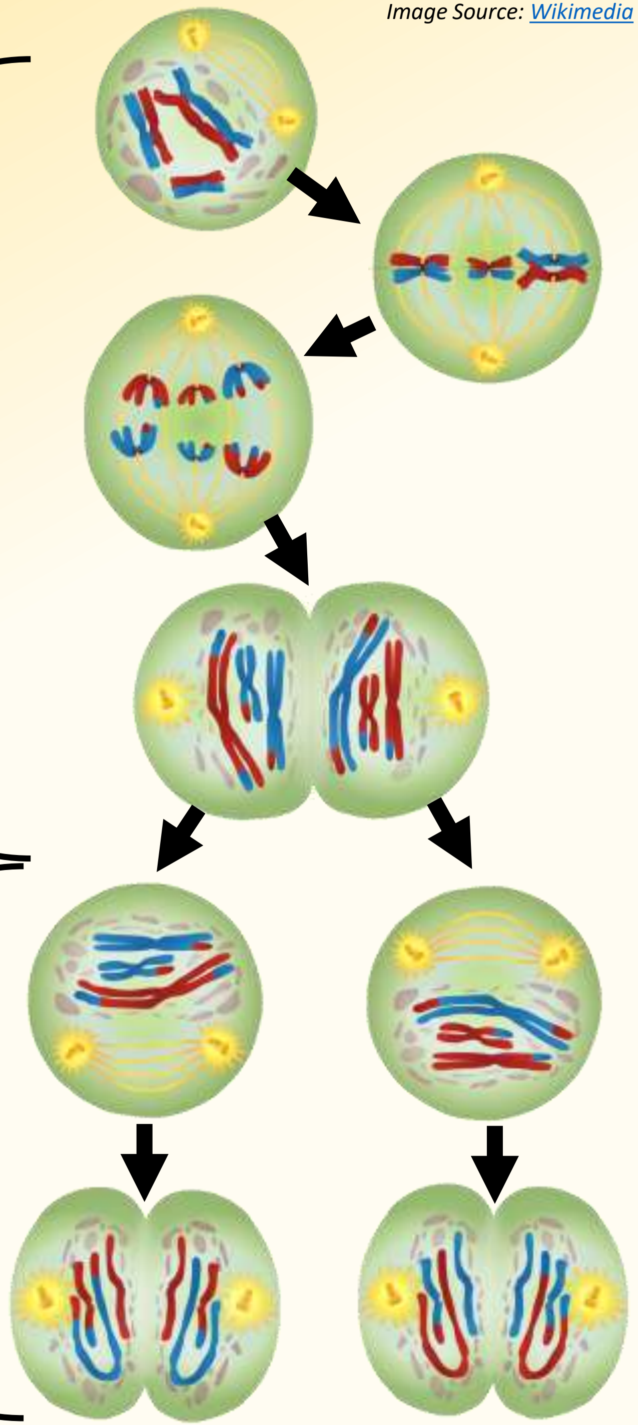


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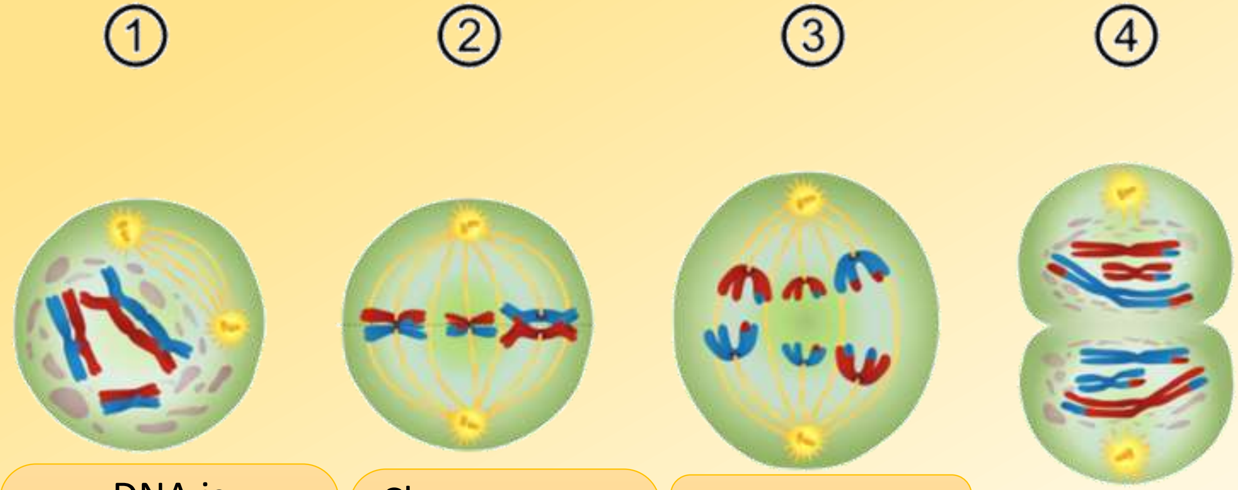
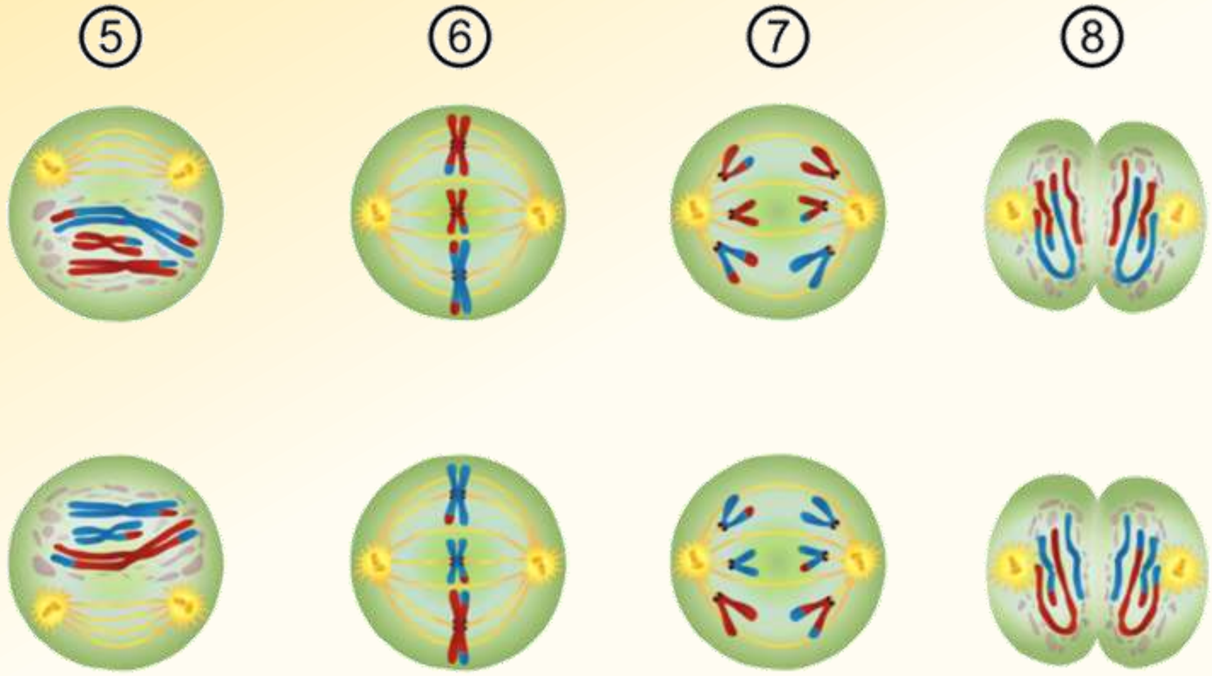
Image Source: Wikimedia

Steps of Meiosis





DNA is duplicated and condenses into chromosomes. →

Chromosomes line up on spindle proteins. →

Chromosomes separate. →

Cell divides, producing two **diploid** cells. →

DNA re-condenses into chromosomes but doesn't duplicate. →

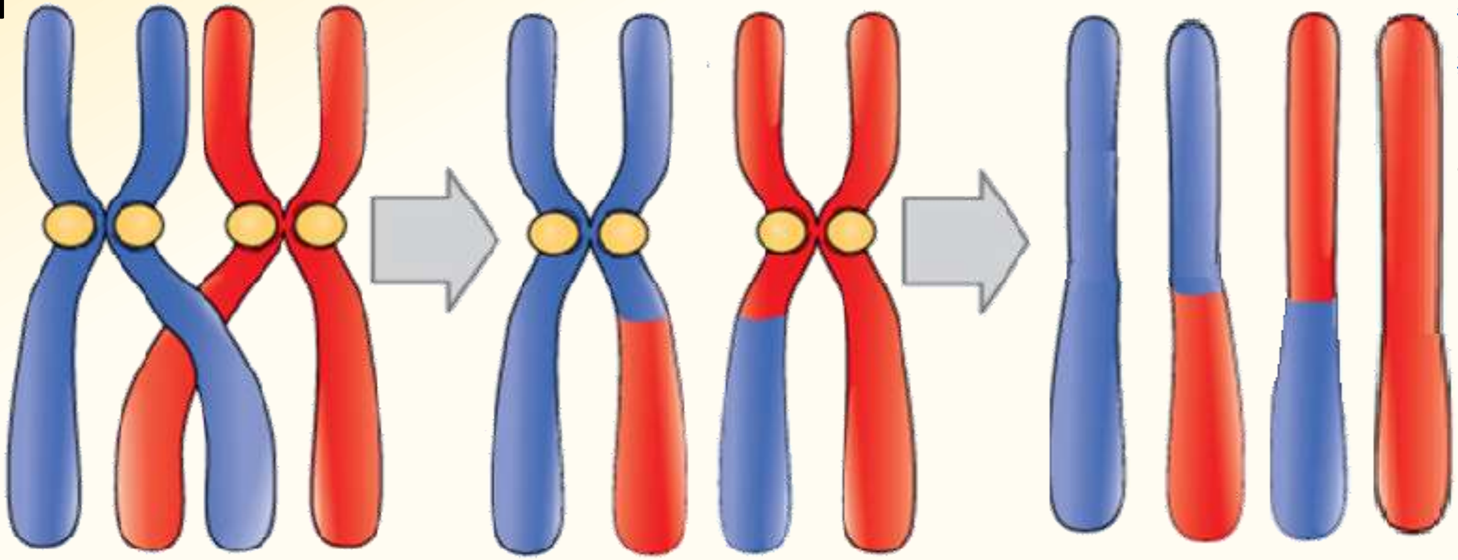
Unduplicated chromosomes line up on spindle proteins. →

Chromosomes separate. →

Cells divide, producing **haploid** cells. These will form sperm/egg cells.

Crossing Over

- **Early in meiosis, after DNA is doubled (from 2 copies to 4 copies of each gene), duplicated chromosome pairs line up on spindle proteins.**
  - As this occurs, pairs of chromosomes will undergo a process called crossing over where duplicated chromosomes can exchange segments of DNA.
- **Crossing over will result in 4 different copies of the *same* chromosome:**
  - A) One entirely comprised of the Parent A's genes,
  - B) One entirely comprised of the Parent B's genes,
  - C) One mostly Parent A and partly Parent B's genes.
  - C) One mostly Parent B and partly Parent A's genes.



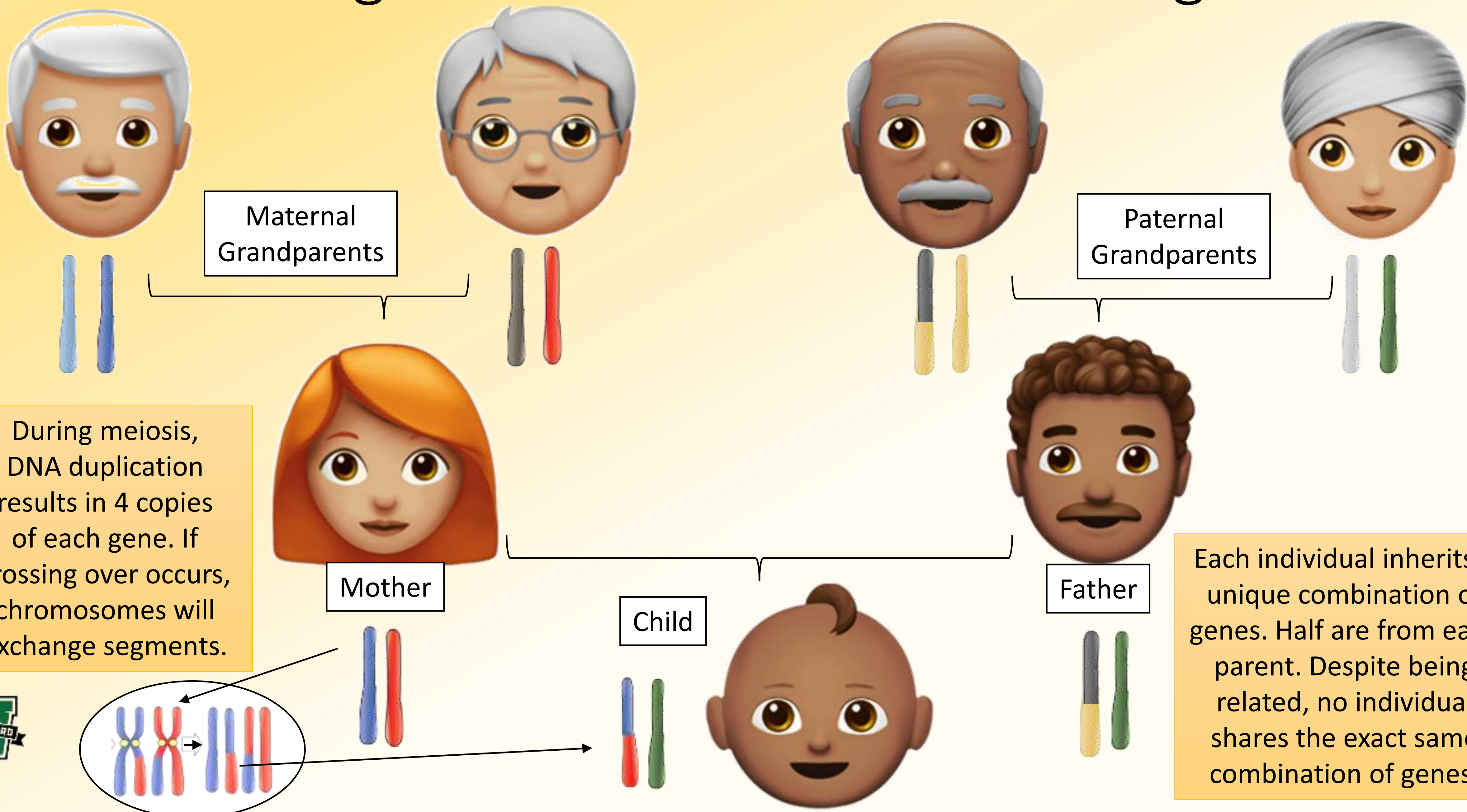
Duplicated chromosomes overlap copies of genes

Chromosomes exchange segments of DNA

Four unique copies of chromosomes emerge

Image Source: Wikimedia

Crossing Over & Generational Changes

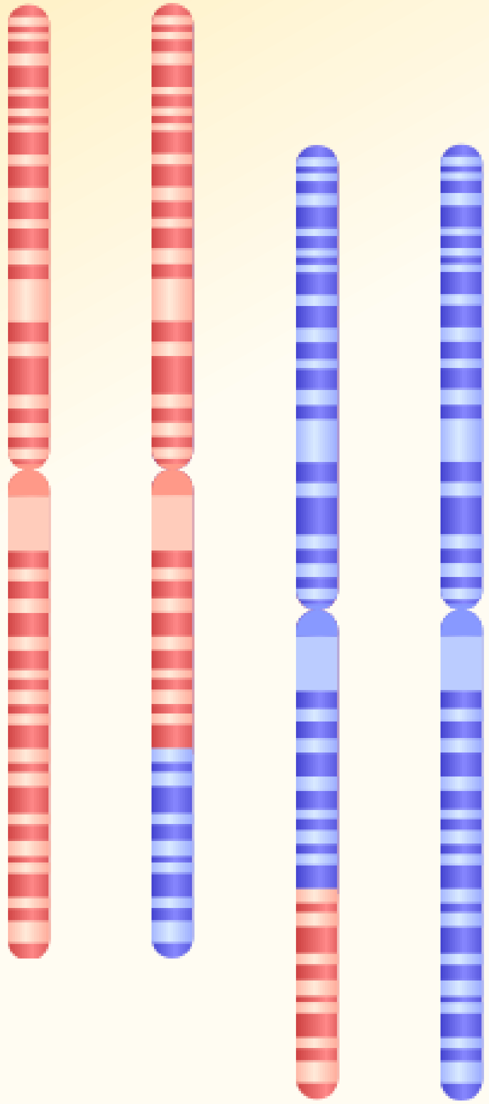


During meiosis, DNA duplication results in 4 copies of each gene. If crossing over occurs, chromosomes will exchange segments.

Each individual inherits a unique combination of genes. Half are from each parent. Despite being related, no individual shares the exact same combination of genes.

Gene Linkage

- **Because of crossing over, each haploid gamete cell (sperm or egg cells) will have a unique combination of genes.**
  - This means that genes on the same chromosome may not always be inherited together.
  - During crossing over, genes from one chromosome will be mixed with genes from a different copy of that same chromosome.
- **The distance between two genes on a chromosome is what determines the likelihood of both of those genes being inherited together by offspring.**
  - The closer that two genes are to each other, the more likely it is that they will be inherited together when an egg cell is fertilized by a sperm cell.
  - This is known as <u>gene linkage</u>.



Genes that are closer to each other are more likely to be inherited together.

Image Source: Wikimedia

Linked Genes & Domestication

- **Gene linkage explains why some traits are associated with each other.**
  - For example, certain hair and eye colors tend to be inherited together, such as blonde hair with blue eyes or brown hair with brown eyes.
  - These traits are found near each other on a chromosome, and so they tend to be inherited together.

- **Gene linkage also explains traits in domesticated species.**
  - For example, domesticated animals tend to have similar traits such as floppy ears, curly tails, and shorter noses.
  - This occurs because the genes associated with docile temperament are near the genes for these physical traits.
  - Whether or not an organism is tame has nothing to do with whether they have floppy ears; these genes just tend to be inherited together because of their proximity on a chromosome.


Wild (top) vs. domesticated (below) pigs.

Image source: [WUHS Ag]()

Fertilization

- **During sexual reproduction, gametes from both parents fuse to form a new cell in a process called <u>fertilization</u>.**
  - Fertilization is how the first cell of a new organism forms.
- **In animals, the nucleus of the sperm cell fuses with the egg cell nucleus.**
  - This turns two haploid gametes into one diploid cell.
  - After fertilization, the new organism will have two copies of each chromosome, with an equal amount of genes from both parents.

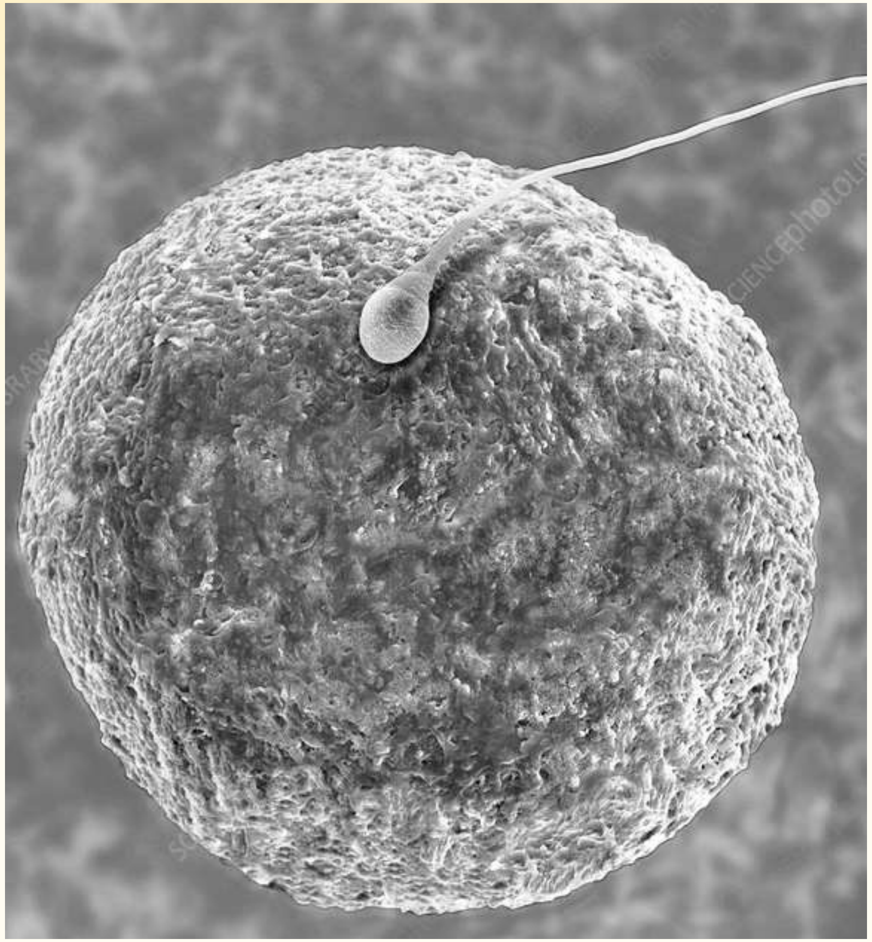
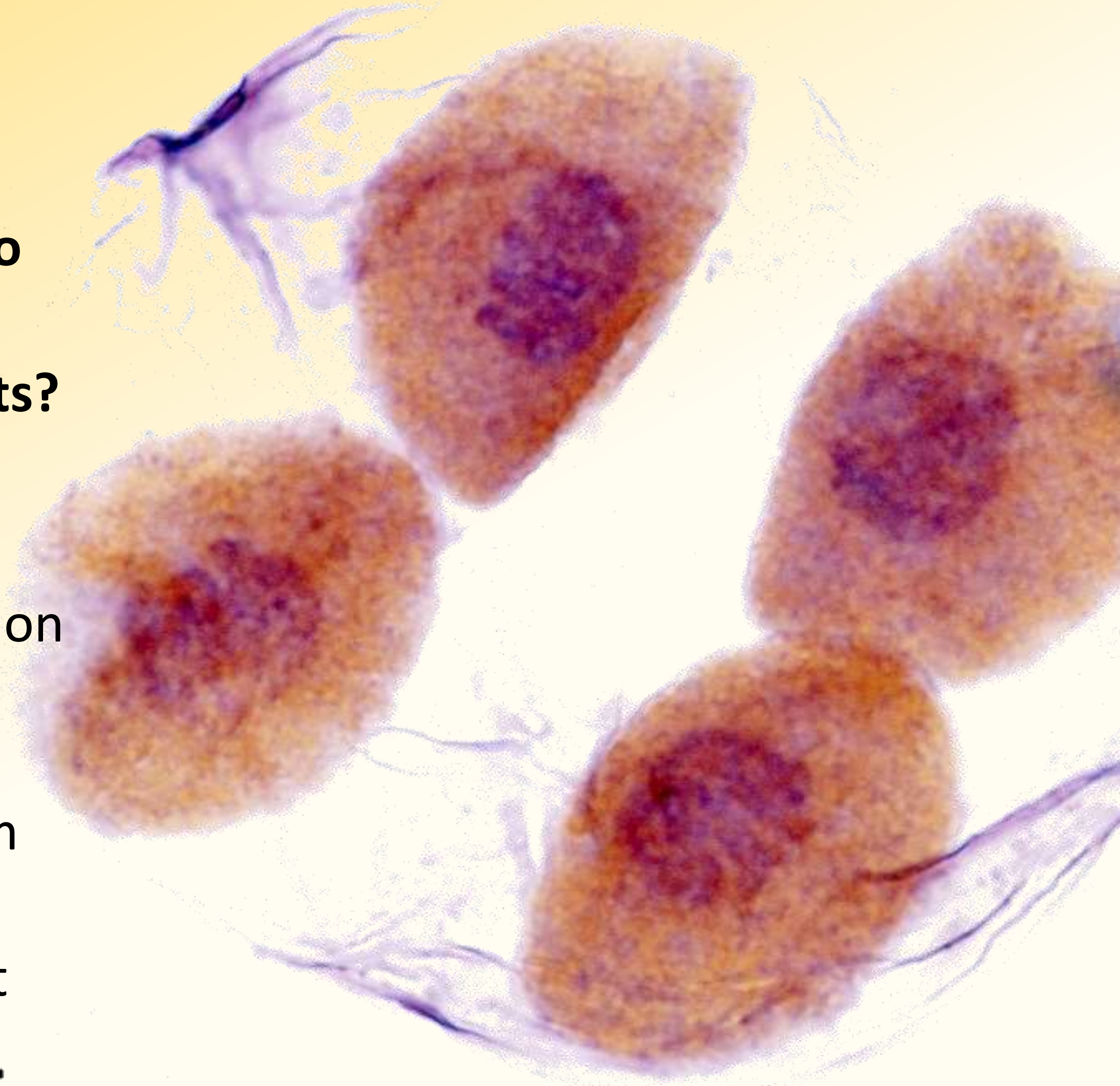


Image Source: [SciencePhoto]

Revising Our Claims

- **Revisit your ideas from Part 1. How could you improve your responses to our Driving Questions?**
- **How are traits inherited from parents?**
- How do organisms of a species reproduce?
- How do different forms of reproduction affect genetic diversity and species survival?
- How do reproductive cells (like sperm and egg cells) form?
- Why do offspring look similar but not identical to their parents?



Looking Ahead:
Part 3 Investigation

- **In Part 3 you will be modeling the steps of meiosis using Play-doh to explain how sperm and egg cells form, and how this increases the genetic diversity of offspring.**

Image Source: Pinterest

Key Points

- **Some organisms can reproduce by <u>asexual reproduction</u>, in which they produce a genetically identical copy of itself.**
- **<u>Sexual reproduction</u> results in offspring that have a mixture of traits from their parents. Most animals and plants reproduce through sexual reproduction.**
- **The primary advantage of sexual reproduction is that it increases the genetic diversity of organisms within a species, which increases the resiliency of a species to disturbances.**
  - The lower the genetic diversity, the greater the risk of widespread loss of individuals within a species due to threats like disease.
- **For sexual reproduction to occur, the organisms of that species must be able to produce cells that each have half the amount of genetic material. These cells are called <u>gametes</u>.**
  - For example, animals produce sperm and egg cells, each with half the number of chromosome.

Key Points

- **The process cell division that produces haploid gamete cells is called <u>meiosis</u>.**
  - Through meiosis, a bodily cell with two copies of each gene (<u>diploid</u>) is changed into a sperm or egg cell with only one copy of each gene (<u>haploid</u>).
- **The process of meiosis shares many similarities with mitosis (regular cell division).**
  - Both begin by replicating the DNA within the cell. Both involve splitting a cell into two cells.
- **The key difference is that mitosis results in identical diploid cells, while meiosis results in genetically unique haploid cells.**
  - While each cell produced through mitosis is identical, every cell produced through meiosis is genetically unique.
- **Meiosis and mitosis both begin with similar steps.**
  - DNA must be duplicated, condensed into chromosomes, attached to spindles, and moved apart before dividing in half and forming two cells.

Key Points

- **In meiosis, a second round of cell division then occurs.**
  - Unlike the first round, DNA is not duplicated. Each of the resulting cells will have half the amount of DNA of a regular diploid cell.
- **During meiosis pairs of chromosomes will undergo a process called crossing over where duplicated chromosomes can exchange segments of DNA.**
  - Crossing over will result in 4 different copies of the *same* chromosome.
- **The closer that two genes are to each other, the more likely it is that they will be inherited together when an egg cell is fertilized by a sperm cell.**
  - This is known as gene linkage.
- **During sexual reproduction, gametes from both parents fuse to form a new cell in a process called fertilization.**

Key Terms

- **<u>Asexual reproduction</u>: producing a genetically identical copy of an organism.**
- **<u>Sexual reproduction</u> results in offspring that have a mixture of traits from their parents.**
- **<u>Gametes</u>: cells that each have half the amount of genetic material (half the number of chromosomes), such as sperm and egg cells.**
- **<u>Meiosis</u>: a process cell division that produces haploid gamete cells.**
- **<u>Diploid</u>: two copies of each gene. <u>Haploid</u>: one copy of each gene.**
- **<u>Crossing over</u>: where duplicated chromosomes can exchange segments of DNA.**
- **<u>Gene Linkage</u>: the closer that two genes are to each other, the more likely it is that they will be inherited together.**
- **<u>Fertilization</u>: gametes from both parents fuse to form a new cell.**