Inheritance of genes
Genes are the units of heredity, and are made up of segments of DNA.
Genes are passed to the next generation via reproductive cells called gametes (sperm and eggs).
Each gene has a specific location called a locus on a certain chromosome.
Most DNA is packaged into chromosomes.

Asexual vs. Sexual Reproduction
In asexual reproduction, a single individual passes genes to its offspring without the fusion of gametes.
A clone is a group of genetically identical individuals from the same parent.
In sexual reproduction, two parents give rise to offspring that have unique combinations of genes inherited from the two parents.

Human somatic cells (any cell other than a gamete) have 23 pairs of chromosomes.
A karyotype is an ordered display of the pairs of chromosomes from a cell.
The two chromosomes in each pair are called homologous chromosomes, or homologs.
Chromosomes in a homologous pair are the same length and shape and carry genes controlling the same inherited characters.

The sex chromosomes, which determine the sex of the individual, are called X and Y.
Human females have a homologous pair of X chromosomes (XX).
Human males have one X and one Y chromosome.
The remaining 22 pairs of chromosomes are called autosomes.

Each pair of homologous chromosomes includes one chromosome from each parent.
The 46 chromosomes in a human somatic cell are two sets of 23: one from the mother and one from the father.
A diploid cell (2n) has two sets of chromosomes.
For humans, the diploid number is 46 (2n = 46).

A gamete (sperm or egg) contains a single set of chromosomes, and is haploid (n).
For humans, the haploid number is 23 (n = 23).
Each set of 23 consists of 22 autosomes and a single sex chromosome.
In an unfertilized egg (ovum), the sex chromosome is X.
In a sperm cell, the sex chromosome may be either X or Y.

Behavior of Cell Cycle
Fertilization is the union of gametes (the sperm and the egg).
The fertilized egg is called a zygote and has one set of chromosomes from each parent.
The zygote produces somatic cells by mitosis and develops into an adult.

At sexual maturity, the ovaries and testes produce haploid gametes.
Gametes are the only types of human cells produced by meiosis, rather than mitosis.
Meiosis results in one set of chromosomes in each gamete.
Fertilization and meiosis alternate in sexual life cycles to maintain chromosome number.

Depending on the type of life cycle, either haploid or diploid cells can divide by mitosis.
However, only diploid cells can undergo meiosis.
In all three life cycles, the halving and doubling of chromosomes contributes to genetic variation in offspring.

Meiosis reduces chromosome number
Like mitosis, meiosis is preceded by the replication of chromosomes.
Meiosis takes place in two sets of cell divisions, called meiosis I and meiosis II.
The two cell divisions result in four daughter cells, rather than the two daughter cells in mitosis.
Each daughter cell has only half as many chromosomes as the parent cell.

Stages of Meiosis
After chromosomes duplicate, two divisions follow:
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.

Division in meiosis I occurs in four phases
Prophase I
Metaphase I
Anaphase I
Telophase I and cytokinesis

Prophase I
Prophase I typically occupies more than 90% of the time required for meiosis.
Chromosomes begin to condense.
In synapsis, homologous chromosomes loosely pair up, aligned gene by gene.
Metaphase I
In metaphase I, tetrads line up at the metaphase plate, with one chromosome facing each pole. Microtubules from one pole are attached to the kinetochore of one chromosome of each tetrad. Microtubules from the other pole are attached to the kinetochore of the other chromosome.

Anaphase I
In anaphase I, pairs of homologous chromosomes separate. One chromosome moves toward each pole, guided by the spindle apparatus. Sister chromatids remain attached at the centromere and move as one unit toward the pole.

Telophase I & Cytokinesis
In the beginning of telophase I, each half of the cell has a haploid set of chromosomes; each chromosome still consists of two sister chromatids. Cytokinesis usually occurs simultaneously, forming two haploid daughter cells.

Division in meiosis II also occurs in four phases:
Prophase II
Metaphase II
Anaphase II
Telophase II and cytokinesis
Meiosis II is very similar to mitosis.

In prophase II, a spindle apparatus forms. In late prophase II, chromosomes (each still composed of two chromatids) move toward the metaphase plate.

Metaphase II
In metaphase II, the sister chromatids are arranged at the metaphase plate. Because of crossing over in meiosis I, the two sister chromatids of each chromosome are no longer genetically identical. The kinetochores of sister chromatids attach to microtubules extending from opposite poles.

Anaphase II
In anaphase II, the sister chromatids separate. The sister chromatids of each chromosome now move as two newly individual chromosomes toward opposite poles.

Telophase II & Cytokinesis
In telophase II, the chromosomes arrive at opposite poles.
Nuclei form, and the chromosomes begin decondensing. Cytokinesis separates the cytoplasm. At the end of meiosis, there are four daughter cells, each with a haploid set of unrelicated chromosomes. Each daughter cell is genetically distinct from the others and from the parent cell.

Mitosis conserves the number of chromosome sets, producing cells that are genetically identical to the parent cell. Meiosis reduces the number of chromosomes sets from two (diploid) to one (haploid), producing cells that differ genetically from each other and from the parent cell.

Events unique to Meiosis
Synapsis and crossing over in prophase I: Homologous chromosomes physically connect and exchange genetic information. At the metaphase plate, there are paired homologous chromosomes (tetrads), instead of individual replicated chromosomes. At anaphase I, it is homologous chromosomes, instead of sister chromatids, that separate.

Sister chromatid cohesion allows sister chromatids of a single chromosome to stay together through meiosis I. Protein complexes called cohesins are responsible for this cohesion. In mitosis, cohesins are cleaved at the end of metaphase. In meiosis, cohesins are cleaved along the chromosome arms in anaphase I (separation of homologs) and at the centromeres in anaphase II (separation of sister chromatids).

Genetic Variation & Evolution
Mutations (changes in an organism’s DNA) are the original source of genetic diversity. Mutations create different versions of genes called alleles. Reshuffling of alleles during sexual reproduction produces genetic variation.

The behavior of chromosomes during meiosis and fertilization is responsible for most of the variation that arises in each generation. Three mechanisms contribute to genetic variation:

- Independent assortment of chromosomes
- Crossing over
- Random fertilization

Independent Assortment
Homologous pairs of chromosomes orient randomly at metaphase I of meiosis. In independent assortment, each pair of chromosomes sorts maternal and paternal homologues into daughter cells independently of the other pairs. The number of combinations possible when chromosomes assort independently into gametes is $2n$, where $n$ is the haploid number.
For humans (n = 23), there are more than 8 million (223) possible combinations of chromosomes.

Crossing Over
Crossing over produces recombinant chromosomes, which combine DNA inherited from each parent. Crossing over begins very early in prophase I, as homologous chromosomes pair up gene by gene.

Importance of Genetic Variation
Natural selection results in the accumulation of genetic variations favored by the environment. Sexual reproduction contributes to the genetic variation in a population, which originates from mutations.