**Heredity and Variation**

All living organisms reproduce. Reproduction results in the formation of offspring of the same kind. A pea plant produces only pea plants each time it reproduces. A rat produces only rats. Humans produce only humans. However, the resulting offspring need not and most often do not totally resemble the parent. Several characteristic differences may occur between individuals belonging to the same species. The similarities and differences among the members of a species are not coincidental. Both the similarities and differences have been received from their parents. The mechanism of transmission of characters, resemblances as well as differences, from the parental generation to the offspring, is called as heredity. The differences shown by individuals within the same species and in the offspring, are described as variations. The scientific study of heredity, variations and the environmental factors responsible for these, is known as genetics.

**Branches of genetics**

* [Behavioural genetics](http://en.wikipedia.org/wiki/Behavioural_genetics): Behavioural genetics is the field of study that examines the role of [genetics](http://en.wikipedia.org/wiki/Genetics) in [animal](http://en.wikipedia.org/wiki/Animal) (including [human](http://en.wikipedia.org/wiki/Human)) [behaviour](http://en.wikipedia.org/wiki/Behaviour).
* [Classical genetics](http://en.wikipedia.org/wiki/Classical_genetics): It is study of mendalian and non mendalian genetics. Classical genetics consists of the techniques and methodologies for study of inheritance based on visible results to identify mechanism of inheritance. A key discovery of classical genetics in [eukaryotes](http://en.wikipedia.org/wiki/Eukaryote) was [genetic linkage](http://en.wikipedia.org/wiki/Genetic_linkage).
* Cytogenetics is a branch of [genetics](http://en.wikipedia.org/wiki/Genetics) that is concerned with the study of the structure and function of the cell, especially the [chromosomes](http://en.wikipedia.org/wiki/Chromosome)
* [Developmental genetics](http://en.wikipedia.org/wiki/Developmental_genetics) : Developmental biology is the study of the process by which organisms grow and develop. Modern developmental biology studies the genetic control of [cell growth](http://en.wikipedia.org/wiki/Cell_growth), [differentiation](http://en.wikipedia.org/wiki/Cellular_differentiation) and "[morphogenesis](http://en.wikipedia.org/wiki/Morphogenesis) which is the process that gives rise to [tissues](http://en.wikipedia.org/wiki/Tissue_%28biology%29), [organs](http://en.wikipedia.org/wiki/Organ_%28anatomy%29) and [anatomy](http://en.wikipedia.org/wiki/Anatomy)
* [Ecological genetics](http://en.wikipedia.org/wiki/Ecological_genetics): Ecological genetics is the study of [genetics](http://en.wikipedia.org/wiki/Genetics) in the context of the interactions among organisms and between the organisms and their environment.
* [Evolutionary genetics](http://en.wikipedia.org/wiki/Evolutionary_genetics): Evolutionary genetics is the broad field of studies that attempts to account for [evolution](http://en.wikipedia.org/wiki/Evolution) in terms of changes in [gene](http://en.wikipedia.org/wiki/Gene) and [genotype](http://en.wikipedia.org/wiki/Genotype) frequencies within [populations](http://en.wikipedia.org/wiki/Population) and the processes that convert the [variation](http://en.wikipedia.org/wiki/Genetic_variation) with populations into more or less permanent variation between [species](http://en.wikipedia.org/wiki/Species). It considers the effect of [micro-evolutionary](http://en.wikipedia.org/wiki/Microevolution) changes among populations due to evolutionary forces, which account for the emergence of [macro-evolutionary](http://en.wikipedia.org/wiki/Macroevolution) patterns in the long term.
* [Genetic engineering](http://en.wikipedia.org/wiki/Genetic_engineering) : Genetic engineering, also called *genetic modification*, is the direct human manipulation of an organism's [genome](http://en.wikipedia.org/wiki/Genome) using modern DNA technology. It involves the introduction of [foreign DNA](http://en.wikipedia.org/wiki/Recombinant_DNA) or [synthetic genes](http://en.wikipedia.org/wiki/Artificial_gene_synthesis) into the organism of interest.
* [Genetics of intelligence](http://en.wikipedia.org/wiki/Genetics_of_intelligence): The study of the heritability of IQ investigates the relative importance of genetics and environment for variation in [intelligence quotient](http://en.wikipedia.org/wiki/Intelligence_quotient) (IQ) in a population. "[Heritability](http://en.wikipedia.org/wiki/Heritability)", in this sense, "refers to the genetic contribution to [variance](http://en.wikipedia.org/wiki/Variance) within a population and in a specific environment
* [Genomics](http://en.wikipedia.org/wiki/Genomics): Genomics is a discipline in [genetics](http://en.wikipedia.org/wiki/Genetics) concerning the study of the [genomes](http://en.wikipedia.org/wiki/Genomes) of organisms. The field includes intensive efforts to determine the entire [DNA sequence](http://en.wikipedia.org/wiki/DNA_sequence) of organisms and fine-scale [genetic mapping](http://en.wikipedia.org/wiki/Genetic_mapping) efforts
* [Human genetics](http://en.wikipedia.org/wiki/Human_genetics) : Human genetics describes the study of inheritance as it occurs in [human beings](http://en.wikipedia.org/wiki/Human_beings). Human genetics encompasses a variety of overlapping fields including: [classical genetics](http://en.wikipedia.org/wiki/Classical_genetics), [cytogenetics](http://en.wikipedia.org/wiki/Cytogenetics), [molecular genetics](http://en.wikipedia.org/wiki/Molecular_genetics), [biochemical genetics](http://en.wikipedia.org/wiki/Biochemical_genetics), [genomics](http://en.wikipedia.org/wiki/Genomics), [population genetics](http://en.wikipedia.org/wiki/Population_genetics), [developmental genetics](http://en.wikipedia.org/wiki/Developmental_genetics), [clinical genetics](http://en.wikipedia.org/wiki/Clinical_genetics), and [genetic counseling](http://en.wikipedia.org/wiki/Genetic_counseling).
* [Medical genetics](http://en.wikipedia.org/wiki/Medical_genetics): Medical genetics is the specialty of [medicine](http://en.wikipedia.org/wiki/Medicine) that involves the diagnosis and management of [hereditary disorders](http://en.wikipedia.org/wiki/Hereditary_disorder). Medical genetics differs from [Human genetics](http://en.wikipedia.org/wiki/Human_genetics) in that human genetics is a field of scientific research that may or may not apply to medicine, but medical genetics refers to the application of genetics to medical care
* [Microbial genetics](http://en.wikipedia.org/wiki/Microbial_genetics): Microbial genetics is a subject area within [microbiology](http://en.wikipedia.org/wiki/Microbiology) and [genetic engineering](http://en.wikipedia.org/wiki/Genetic_engineering). It studies the genetics of [very small (micro) organisms](http://en.wikipedia.org/wiki/Microorganism). This involves the study of the [genotype](http://en.wikipedia.org/wiki/Genotype) of microbial species and also the [expression system](http://en.wikipedia.org/wiki/Gene_expression#Expression_system) in the form of [phenotypes](http://en.wikipedia.org/wiki/Phenotype).It also involves the study of genetic processes taking place in these micro organisms i.e., recombination etc
* [Molecular genetics](http://en.wikipedia.org/wiki/Molecular_genetics): Molecular genetics is the field of [biology](http://en.wikipedia.org/wiki/Biology) and [genetics](http://en.wikipedia.org/wiki/Genetics) that studies the structure and function of [genes](http://en.wikipedia.org/wiki/Gene) at a [molecular](http://en.wikipedia.org/wiki/Molecule) level. The field studies how the genes are transferred from generation to generation. Molecular genetics employs the methods of [genetics](http://en.wikipedia.org/wiki/Genetics) and [molecular biology](http://en.wikipedia.org/wiki/Molecular_biology)
* [Population genetics](http://en.wikipedia.org/wiki/Population_genetics) : Population genetics is the study of [allele frequency](http://en.wikipedia.org/wiki/Allele_frequency) distribution and change under the influence of the four main evolutionary processes: [natural selection](http://en.wikipedia.org/wiki/Natural_selection), [genetic drift](http://en.wikipedia.org/wiki/Genetic_drift), [mutation](http://en.wikipedia.org/wiki/Mutation) and [gene flow](http://en.wikipedia.org/wiki/Gene_flow). It also takes into account the factors of [recombination](http://en.wikipedia.org/wiki/Recombination), population subdivision and [population structure](http://en.wikipedia.org/wiki/Population_structure). It attempts to explain such phenomena as [adaptation](http://en.wikipedia.org/wiki/Adaptation_%28biology%29) and [speciation](http://en.wikipedia.org/wiki/Speciation)
* [Psychiatric( Behavioural ) genetics](http://en.wikipedia.org/wiki/Psychiatric_genetics): Psychiatric genetics, a subfield of [behavioral neurogenetics](http://en.wikipedia.org/wiki/Behavioural_genetics), studies the role of genetics in psychological conditions such as [alcoholism](http://en.wikipedia.org/wiki/Alcoholism), [schizophrenia](http://en.wikipedia.org/wiki/Schizophrenia), [bipolar disorder](http://en.wikipedia.org/wiki/Bipolar_disorder), and [autism](http://en.wikipedia.org/wiki/Autism). The basic principle behind psychiatric genetics is that genetic [polymorphisms](http://en.wikipedia.org/wiki/Polymorphism_%28biology%29), as indicated by linkage to e.g. a [single nucleotide polymorphism](http://en.wikipedia.org/wiki/Single_nucleotide_polymorphism) (SNP), are part of the [etiology](http://en.wikipedia.org/wiki/Etiology) of [psychiatric disorders](http://en.wikipedia.org/wiki/Mental_illness)
* [Quantitative genetics](http://en.wikipedia.org/wiki/Quantitative_genetics): It is the study of continuous traits (such as height or weight) and their underlying mechanisms. It is effectively an extension of simple [Mendelian inheritance](http://en.wikipedia.org/wiki/Mendelian_inheritance) in that the combined effect of the many underlying genes results in a [continuous distribution](http://en.wikipedia.org/wiki/Continuous_probability_distribution) of [phenotypic](http://en.wikipedia.org/wiki/Phenotypic) values.
* Human genetics-The genetics of man
* Biochemical genetics-It provides the biochemical explanations of various genetical
* Clinical genetics-It applies genetical analysis in diagnosing various hereditary diseases in man and suggests the possible cures for them.
* Developmental genetics-It applies genetical knowledge to the developmental biology
* Radiation genetics-It deals with the genetical effects of radiations on the living organisms.

**GENETIC TERMS**

**Cross** - Mating of two organisms.

**Offspring** - Results of a cross; "young" produced by cross.
**Gene** - Section of a chromosome that carries the information for a specific trait.

**Dominant Allels** - Gene/trait that appears or expresses itself; shown with a capital letter (e.g. Tall = T, Brown = B, etc.).

**Recessive allels** - Gene/trait that is hidden in the presence of a dominant; shown with a small, or lower-case, letter (e.g. short = t, blue = b, etc.). **Genotype** – Genetic makeup of an organism, it is the representation of genetic constitution with respect to one character or a pair of characters. (e.g. TT, Tt, tt).

**Phenotype**- it is observable Physical appearance of an organism (e.g. tall, short).Usually the appearance of the dominant gene, or the recessive if it is a purebred trait

**Allele:** Alternate forms of a gene. Code for a pair of contrasting traits. They are alternative forms of a genetic *locus*; a single allele for each locus is inherited separately from each parent (e.g., at a locus for eye color the allele might result in blue or brown eyes).

 **Hybrid** - Organism with different alleles/genes for a trait (see heterozygous) .

**Purebred** - Organism with identical alleles/genes for a trait (see homozygous).

**Sex chromosomes** - The chromosomes that determine the sex or gender of an organism. An organism with two X chromosomes (XX) is a female. An organism with one X chromosome and one Y chromosome (XY) is a male

**Autosome:** A *chromosome* not involved in sex determination. The *diploid* human *genome* consists of 46 chromosomes, 22 pairs of autosomes, and 1 pair of *sex chromosomes* (the X and Y chromosomes).

**Cloning:** The process of asexually producing a group of cells (clones), all genetically identical, from a single ancestor. In *recombinant DNA technology*, the use of DNA manipulation procedures to produce multiple copies of a single *gene* or segment of DNA is referred to as cloning

**Crossing over:** The breaking during *meiosis* of one maternal and one paternal *chromosome*, the exchange of corresponding sections of DNA, and the rejoining of the chromosomes. This process can result in an exchange of alleles between chromosomes.

**Diploid:** A full set of genetic material, consisting of paired *chromosomes* one chromosome from each parental set. Most animal cells except the *gametes* have a diploid set of chromosomes. The diploid human *genome* has 46 chromosomes.

**Gamete:** Mature male or female reproductive cell (sperm or ovum) with a *haploid* set of *chromosomes* (23 for humans).

**Gene:** The fundamental physical and functional unit of heredity. A *gene* is an ordered sequence of *nucleotides* located in a particular position on a particular *chromosome* that encodes a specific functional product (i.e., a *protein* or *RNA molecule*). or

The fundamental unit of heredity; a segment of DNA found at a fixed location on a chromosome that codes for a single [polypeptide](http://www.emunix.emich.edu/~rwinning/genetics/glossary.htm#polypeptide)

**Gene expression:** The process by which a *genes* coded information is converted into the structures present and operating in the cell. Expressed genes include those that are transcribed into *mRNA* and then translated into *protein* and those that are transcribed into *RNA* but not translated into protein

**Genetic code:** The sequence of *nucleotides*, coded in triplets (*codons*) along the *mRNA*, that determines the sequence of *amino acids* in *protein* synthesis. The DNA sequence of a *gene* can be used to predict the mRNA sequence, and the genetic code can in turn be used to predict the *amino acid* sequence.

**Diploid** The condition of having two of each chromosome. [Somatic](http://www.emunix.emich.edu/~rwinning/genetics/glossary.htm#somatic) cells of higher plants and animals are normally diploid

**Haploid:** A single set of *chromosomes* (half the full set of genetic material), present in the egg and sperm cells of animals and in the egg and pollen cells of plants. Human beings have 23 chromosomes in their reproductive cells.

**Homologous chromosomes:** A pair of *chromosomes* containing the same linear *gene* sequences, each derived from one parent

**Karyotype:** A photomicrograph of an individual’s *chromosomes* arranged in a standard format showing the number, size, and shape of each chromosome type; used in low- resolution *physical mapping* to correlate gross chromosomal abnormalities with the characteristics of specific diseases.

**Backcross** A cross between an F1[heterozygote](http://www.emunix.emich.edu/~rwinning/genetics/glossary.htm#heterozygote) and an individual with the parental [genotype](http://www.emunix.emich.edu/~rwinning/genetics/glossary.htm#genotype).

**Carrier** An individual ([heterozygotic](http://www.emunix.emich.edu/~rwinning/genetics/glossary.htm%22%20%5Cl%20%22heterozygote)) who carries a recessive [allele](http://www.emunix.emich.edu/~rwinning/genetics/glossary.htm#allele), but does not express it.

**Alleles of Allelomorphs**
A pair of genes controlling the same character and located at the same locus in the homologous chromosomes are known as The fourth combination **alleles**  or**allelomorphs.** Eg. The gene content of the F1 plant is **Tt.** These two genes are called alleles because they are located in the same locus of homologous chromosomes. So **T** is allelic to **t** or vice versa.
Each alternative of a character is controlled by a gene. For example, tallness is controlled by a gene **T** and its alternative character dwarfness is controlled by a gene **t**. The two genes (**T** and **t)** representing the two alternatives (Tall and dwarf) of a particular character (height) are present **in two separate chromosomes (homologous chromosomes).** These genes are located in the same locus on the homologous chromosomes.
**Homozygote**
Homozygote (**Homo =** similar, **Zygous =** pair) is an individual carrying indentical genes for a particular character. This genotype is called **homozygous  genotype**and the organism is called **homozygous organism.** Homozygotes produce only one kind of gametes. They always breed true.

When both genes of a homozygote are dominant the genotype is called **homozygous dominant.** Eg.Tall parent (**TT)** of Mendel’s experiment.
When both genes of homozygote are recessive the genotype is called **homozygous recessive.** Eg. Dwarf parent (**tt**) of Mendel’s experiment

 **Hoterozygote**
Heterozygote (**Hetero**= dissimilar, **Zygous** = pair) is an organism carrying non-identical genes for a particular character. This genotype is called **heterozygous genotype** and the individual is called **heterozygous organism.**
Heterozygotes produce two types of gamete. They never breed true. Eg The F1 plant of Mendel’s experiment is a heterozygote (**Tt**).

**Genotype and phenotype**
The genetic make-up or the gene content of a plant or an animal is called **genotype.**The genotype of the tall parent is **TT.** The genotype of the dwarf parent is **tt**  and the genotype of the F1 plant is **Tt.**
In the F2 generation of Mendel’s experiment, gentotypically, there are three types of plants. They are 25% **TT** (homozygous); 50% **Tt** (heterozygous) and 25% **tt** (homozygous). This gives a 1 : 2 :1 ratio. This ratio is called **genotypic ratio,** because it is based on the genetic make-up of the individual.

Hybrid
A hybrid is an organism resulting from a cross between two different parents. Eg. The F1 plants of Mendel’s experiments.
The hybrid resulting from a cross between two parents different in only one character is called a monohybrid. The F1 plant of Mendel’s monohybrid experiment is a monohybrid (Tt).

The hybrid resulting from a cross between two parents differing in two characters is called as dihybrid. The F1 plant of Mendel’s dihybrid experiment is a dihybrid (YyRr)

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| --- | --- | --- |
| **No.**  | **Genotype** | **Phenotype** |
| 1 | Genotype is the gene composition of an organism which determines the characters. | Phenotype refers to the visible character of an organism. |
| 2 | Genotype can be ascertained from the ancestry of the individuals. Individuals having genotype usually have the same phenotype | Phenotype can be read out from the individuals be direct observation. Individuals having identical phenotype may not have the same genotype. |