Chapter 4 Heridity

Introduction to heredity and inheritance

Heredity is the process by which traits are passed from parents to their offspring. This occurs through genes, which are units of heredity located in DNA. All living organisms reproduce to continue their species, and the similarity between parents and offspring is due to inheritance.

Definition and causes of variations

Variations refer to differences in traits among individuals of the same species. These differences arise due to changes in DNA caused by mutations, genetic recombination, or environmental influences.

Variations are differences seen among individuals of the same species. These arise due to:

- Genetic recombination (most common during sexual reproduction)
- Mutations (random changes in DNA)
- Environmental factors

Variations can be seen in both asexual and sexual reproduction. In asexual reproduction, offspring are produced by a single parent without genetic mixing, resulting in genetically identical offspring. In Sexual reproduction, Offspring receive genetic material from both parents, leading to higher variations and unique traits.

Variations in asexual reproduction

Asexual reproduction produces offspring that are mostly genetic clones of the parent, resulting in very little variation. However, small variations can still occur due to mutations, which are random changes in DNA. For example, in a group of sugar cane plants reproducing asexually, most plants are identical, but a mutation in one plant could cause slight differences such as in leaf shape or growth pattern.

Variations in sexual reproduction

Variations in sexual reproduction, where offspring result from the fusion of male and female gametes, inheriting genetic material from both parents. This leads to unique traits and characteristics among offspring, such as differences in coat color, size, ear shapes, or behaviors in animals like dogs. The high level of variation is due to genetic recombination, which mixes DNA from both parents to create new trait combinations, making no two offspring identical even within the same species.

Over generations, small variations accumulate, enhancing diversity in populations. Some variations may help organisms adapt better, which ties into the concept of natural selection.

Accumulation and importance of variations

Variations accumulate over generations, driving diversity. Advantageous variations enhance survival (e.g., heat-resistant bacteria surviving a heat wave), leading to natural selection, while neutral or disadvantageous variations may not persist.

Types of traits

- Inherited traits: Passed genetically from parents like eye or hair color, are genetically determined, fixed at birth, and contribute to evolution. These are fixed and influence evolution.
- Acquired traits: Developed during an individual's lifetime due to environment or behavior such as language skills or dancing and are environmentally influenced. These are not genetic and do not influence evolution

Inheritance and role of Genes

Traits are controlled by genes, which are inherited from both parents. Each trait is determined by a pair of alleles — Offspring inherit equal DNA from both parents, with genes controlling traits like eye color. Each trait is governed by two alleles (one from each parent). For example, a brown eye allele (dominant) from the father and a blue eye allele (recessive) from the mother may result in brown eyes due to dominance.

Dominant and recessive traits explained

The brown eye color gene is dominant over the blue eye color gene, meaning the brown trait is expressed when dominant alleles are present. A dominant trait is expressed if at least one dominant allele is present, while a recessive trait is expressed only when both alleles are recessive. This introduces the basic concept of inheritance of traits. The systematic study of inheritance patterns began in the 19th century with Gregor Johann Mendel, who was the first to analyze these patterns scientifically.

Mendel's experiments with pea plants

Mendel proposed three laws of inheritance based on his experiments with pea plants (Pisum sativum). He chose pea plants because of their short life cycle, ability to self-pollinate and cross-pollinate easily, and distinct, easily observable traits such as seed color, flower color, and plant height. Mendel used contrasting traits like tall vs. short plants, yellow vs. green seeds, and round vs. wrinkled seeds to analyze inheritance patterns. He conducted monohybrid crosses, which involve breeding individuals differing in a single trait, such as crossing pure-bred tall and short pea plants to study trait inheritance.

Monohybrid cross and genetic ratios

In monohybrid crosses, he studied single traits, like plant height. Crossing pure-bred tall (TT) and short (tt) plants produced all tall F1 offspring (Tt). Self-pollinating F1 plants yielded an F2 generation with a 3:1 phenotypic ratio (tall:short) and a 1:2:1 genotypic ratio (TT:Tt:tt), shown via Punnett squares.

Dihybrid cross and phenotypic ratios

In dihybrid crosses, Mendel examined two traits (e.g., round yellow vs. green wrinkled seeds), observing a 9:3:3:1 phenotypic ratio in the F2 generation, demonstrating independent trait inheritance.

Mendel's laws of inheritance

Gregor Johann Mendel, through his experiments with pea plants, established three fundamental laws that form the basis of classical genetics. The Law of Dominance states that when two different alleles are present for a trait, one may mask the expression of the other; the expressed one is called the dominant allele, while the masked one is recessive. For example, in pea plants, the allele for tallness is dominant over the allele for shortness. The Law of Segregation explains that each organism carries two alleles for each trait, but only one allele from each parent is passed to the offspring during gamete formation. These alleles separate, or segregate, during the formation of gametes, ensuring offspring receive one allele from each parent. Finally, the Law of Independent Assortment states that alleles for different traits are distributed to gametes independently of one another. This means the inheritance of one trait (like flower color) does not influence the inheritance of another trait (like seed shape). Mendel's laws explain how traits are inherited in predictable patterns, laying the groundwork for modern genetics.

Gene expression and chromosome basics

The Law of Independent Assortment explains that alleles of different genes segregate independently during gamete formation. Traits are expressed through proteins made using the genetic information in DNA. A gene is a DNA segment coding for a specific protein. For example, plant growth depends on a growth hormone, which requires an enzyme protein controlled by a gene. If the gene functions properly, sufficient hormone is produced, resulting in tall plants; if altered, less enzyme and hormone are produced, causing shorter plants. This illustrates how genes influence physical traits.

Genes controlling traits are located on chromosomes, which exist in pairs within cells. Each chromosome pair carries two alleles for a trait, but these alleles are not on the same DNA strand. Cells normally have two chromosome sets, but gametes receive only one set because they are haploid. During gamete formation, only one allele from each gene pair is passed on. When gametes fuse during fertilization, the resulting organism inherits a pair of genes for each trait.

Sex determination in humans and animals

The sex of a newborn is determined by different factors depending on the species. In reptiles like snakes and crocodiles, environmental temperature influences sex, while some snails can change their sex. However, in humans, sex is genetically determined by the chromosomes inherited from the parents. Each human cell contains 23 pairs of chromosomes, including one pair of sex chromosomes. Females have two X chromosomes (XX), and males have one X and one Y chromosome (XY). Gametes (sex cells) are haploid, containing only 23 chromosomes: 22 autosomes and one sex chromosome. In males, sperm cells carry either an X or Y chromosome, while all female egg cells carry an X chromosome. The combination of these chromosomes during fertilization determines the sex of the child: XY results in a male and XX results in a female.