CHAPTER 05

Heredity and variations

The principle of **"like begets like"** is a fundamental and widespread occurrence in life. Essentially, it means that living organisms give birth to offspring that resemble themselves. **Genetics** is the scientific discipline that examines hereditary traits and **variations**.

Inheritance refers to the transfer of traits or characteristics from parents to their offspring, from one generation to the next. This process forms the foundation of heredity, and genes are the fundamental units of inheritance.

Variation, on the other hand, refers to the degree of difference between offspring and their parents. Essentially, it's a measure of how much individuals in a population differ from one another.

Genetic Terminology:

Genes or **factors** are structures located on chromosomes that transfer hereditary characteristics from one generation to the next. They are the fundamental units of DNA.

Alleles are alternative forms of genes for a single trait or characteristic, such as the color of a flower (red or white) or stem height (tall or dwarf).

Homozygous refers to a diploid condition in which both alleles are the same, for example, TT or tt.

Heterozygous refers to a diploid condition in which both alleles are different, such as Tt.

A **monohybrid cross** involves only one pair of characters.

A **dihybrid cross** involves two pairs of characters.

Reciprocal cross refers to a cross where the sexes of the parents are reversed.

A **backcross** is a cross between a homozygous dominant parent and a heterozygous F1 hybrid.

A **testcross** is a cross between a homozygous recessive parent and a heterozygous F1 hybrid. It can help identify whether a plant is homozygous or heterozygous.

Mendel's Experiment

Mendel spent seven years conducting experiments on garden pea to study inheritance patterns. During his research, he employed statistical analysis and mathematical logic. He focused on seven contrasting traits of the pea plant, including

1. **stem height** (tall and dwarf)
2. **Flower position** (axial and terminal)
3. **Pod colour** (green and yellow)
4. **pod shape** (inflated and constricted)
5. **seed shape** (round and wrinkled)
6. **flower colour** (purple and white)
7. **seed coat colour** (yellow and green).

Mendel's Laws of Inheritance. Laws

A. Law of Dominance

According to Mendel, characters are controlled by discrete units known as ***factors***, which occur in pairs. In a pair of dissimilar factors, one member of the pair is *dominant* while the other is *recessive*. This is the ***Law of Dominance***.

B. Law of Segregation

Mendel's second law, the Law of Segregation, states that during gamete formation, parents contain two alleles. The factors or alleles of a pair segregate from each other, such that a gamete receives only one of the two factors.

Generation/ratio	F1	F2
Phenotypic	1	3:1
Genotypic	1	1:2:1

C. Law of Independent Assortment

The Law of Independent Assortment, Mendel's third law, states that the inheritance of one trait is independent of the inheritance of another trait. In other words, the distribution of alleles for one gene does not affect the distribution of alleles for another gene.

Generation/ratio	F1	F2
Phenotypic	1	9:3:3:1
Genotypic	1	1:2:2:4:1:2:1:2:1

In conclusion, Mendel's observations and laws provide a solid foundation for understanding the mechanisms behind genetic inheritance, and his work remains a foundation of modern genetics.

Deviations from Mendel's

Although Mendel's principles are a significant foundation for understanding inheritance patterns, some genetic phenomena cannot be explained by his laws. The examples of which include:

Incomplete dominance occurs when the phenotype of the F1 hybrid offspring is not identical to either parent, but instead displays an ***intermediate expression*** between the two alleles in their homozygous states. This results in both phenotypic and genotypic ratios of **1:2:1**, as seen in the flower color of **Mirabilis jalapa.**

Codominance is a phenomenon in which two alleles independently express themselves in an organism when present together. An example of this is the **ABO blood group in humans.**

Multiple alleles refer to more than two alternative forms (alleles) of a gene that occupy the same locus on a chromosome in a population. A well-known example of multiple alleles is the **ABO blood group system.**

The human ABO blood group system has different blood groups, which are determined by the presence or absence of ***antigens (A and B)*** on the surface of red blood cells (RBCs). Additionally, the blood plasma contains ***antibodies*** that react against antigens that are not present on the individual's own RBCs. Depending on the genotype, individuals can donate blood to and receive blood from certain blood groups.

The blood groups and their corresponding genotypes, antigens, antibodies, and transfusion compatibility are summarized in the following table:

Blood groups	**Antigen in RBC**	**Antibody in plasma**	**Can donate blood to**	**Can accep blood fron**
O (universal donor)	None	A, B	A, B, AB, O	O
AB (universal acceptor)	Aor B	None	AB	A, B, AB,
B	B	A	AB, B	O, B
A	A	B	AB, A	O, A

To summarize, multiple alleles are alternative forms of a gene that occupy the same locus on a chromosome in a population. The ABO blood group system is an example of multiple alleles, where different blood groups are determined by the presence or absence of antigens and antibodies in plasma.

Polygenic inheritance refers to the way traits are inherited through the contribution of multiple genes, where each gene plays a small role in determining the final phenotype. An example of this is **human skin color**.

pleiotropy is a phenomenon where a single gene can have multiple effects on the phenotype. For instance**, sickle-cell anemia, white eye in Drosophila, and phenylketonuria (PKU)** are examples of genetic disorders that exhibit pleiotropy.

Chromosomal Theory of inheritance

1. The Chromosomal Theory of Inheritance was put forward in 1902 by **Boveri** and **Sutton**.
2. It is a fundamental and unifying theory of genetics.
3. The theory identifies ***chromosomes*** as the carriers of genetic material.
4. According to this theory, genetic information is passed down from one generation to the next through the chromosomes.
5. Each chromosome contains many genes, which are responsible for specific traits or characteristics.
6. Chromosomes come in ***pairs***, with one chromosome from each parent, and they separate during the process of ***meiosis***.
7. The theory also explains how genetic ***mutations*** and changes can occur during meiosis, leading to ***genetic variation***.
8. The Chromosomal Theory of Inheritance has been widely accepted and has led to many important discoveries in genetics.

Crossing over

- Crossing Over refers to the process of exchange of genetic material between *non-sister chromatids of homologous chromosomes.*
- This exchange occurs during meiosis and results in the creation of new combinations of alleles in the gametes.
- The process of crossing over increases *genetic diversity* and is essential for the proper segregation of chromosomes during meiosis.
- **Linkage** is the physical association of two genes located close to each other on the same chromosome.
- Genes that are located close to each other on the same chromosome tend to be inherited together, which is called ***genetic linkage.***
- **Recombination** refers to the generation of new combinations of alleles that are different from the parental combinations.
- Recombination can occur during meiosis when homologous chromosomes exchange genetic material through crossing over.

Linkage and **recombination** are important concepts in genetics, and they have played a significant role in our understanding of inheritance patterns and the genetic basis of diseases.

Sex determination

Sex determination is the process by which an individual's sex is established through differential development at the time of **zygote formation.**

There are different types of sex determination mechanisms observed in various organisms.

1. **Male heterogamety** is a sex determination mechanism where males have only one X chromosome (called XO), while females have two X chromosomes (XX). Examples of male heterogamety include the XX-XO type observed in insects like grasshoppers and the XX-XY type observed in insects like Drosophila melanogaster and humans.
2. **Female heterogamety** is a sex determination mechanism where females produce two different types of gametes. Examples of female heterogamety include the ZZ-ZW type observed in birds, fowls, and fishes, and the ZZ-ZO type observed in butterflies and moths.
3. **Haplo-diploidy** is another sex determination mechanism observed in insects like honeybees and wasps, where males develop from unfertilized eggs and are haploid, while females develop from fertilized eggs and are diploid.

Based on the type of allosomes present in the gamete, parents can be classified as either ***homogametic*** (producing similar gametes) or ***heterogametic*** (producing different gametes).

Sex determination in humans

The determination of sex in humans relies on the combination of gametes during fertilization. Males produce two types of gametes: X and Y, while females only produce X gametes. When an ovum is fertilized with a sperm carrying an X chromosome, the resulting zygote develops into a female (XX). Conversely, if the sperm carries a Y chromosome, the zygote develops into a male (XY). Therefore, the sex of a child is determined by the type of sperm that fertilizes the ovum.

Mutation

Mutation is a ***sudden***, ***stable***, and ***inheritable*** change that occurs in the genetic material or DNA sequences of an organism. The organism that undergoes mutation is known as a ***mutant***.

The ***factors*** that Induce mutations are called ***mutagens***, and they can be ***chemical*** or ***physical agents*** such as ***UV radiation***.

There are different types of mutations, including ***point mutation***, which is caused by a change in a single base pair of DNA, and ***frameshift mutation***, which refers to deletions and insertions of base pairs in DNA.

The ***loss or gain*** of a ***segment of DNA*** can result in structural alterations in chromosomes because genes are located on chromosomes.

During meiosis, when the members of a homologous pair of chromosomes fail to segregate, ***aneuploidy*** occurs. This leads to the loss or gain of one or more chromosomes, which can cause ***monosomy***, i.e., the lack of one chromosome of normal complement, or ***trisomy***, i.e., three instead of the normal two chromosomes.

Polyploidy occurs when there is a failure of cytokinesis after the telophase stage of cell division, resulting in an increase in a whole set of chromosomes in an organism.

Pedigree analysis

Pedigree analysis is a method of studying inherited traits in a human family by creating a ***family tree*** or ***diagram*** that tracks the trait through multiple generations.

Genetic disorders

Genetic disorders refer to illnesses or conditions that are caused by abnormalities in a person's ***autosomes or sex chromosomes***. Autosomal disorders are caused by mutations in genes located on the autosomes, while sex-linked disorders are caused by mutations in genes located on the sex chromosomes.

Mendelian disorders

Mendelian disorders are determined by ***alterations in a single gene***, and can be either recessive or dominant. Examples of Mendelian disorders include **color blindness, haemophilia, sickle-cell anemia, phenylketonuria, and thalassemia.**

Color Blindness: This disorder affects a person's ability to distinguish between red and green colors. The gene that controls this disorder is located on the X chromosome and is recessive.

Haemophilia: This disorder is caused by an X-linked recessive gene and affects a person's ability to form blood clots when injured. Continuous bleeding can be life-threatening for people with this disorder.

Sickle-cell Anemia: This is an autosomal recessive trait that can be inherited from both parents when they are carriers of the gene (heterozygous). In this disorder, the substitution of valine by glutamic acid changes the shape of the red blood cells to a sickle-like structure.

Phenylketonuria (PKU): This is an inborn error of metabolism inherited as an autosomal recessive trait. People with PKU lack the enzyme that converts phenylalanine to tyrosine, leading to the accumulation of toxic substances in the body. Its gene is associated with the 12^{th} chromosome.

Thalassemia: This is an autosomal recessive disease that occurs due to either mutation or deletion of genes, resulting in a reduced rate of synthesis of one of the globin chains (α or β) of hemoglobin.

Chromosomal disorders, on the other hand, are caused by the absence, excess, or abnormal arrangement of one or more chromosomes. Examples of chromosomal disorders include **Down's syndrome, Turner's syndrome, and Klinefelter's syndrome.**

(i) **Down's Syndrome**, also known as Mongolism, is caused by the presence of an ***extra copy of chromosome number 21 in autosomes***, a condition known as trisomy. People with Down's Syndrome typically exhibit short stature, a furrowed tongue, and slow motor and mental development.

(ii) **Turner's Syndrome**, on the other hand, is caused by the absence of one X-chromosome in females, resulting in 45 chromosomes **(44+X)**. Symptoms of Turner's Syndrome include infertility, a less developed uterus, short stature, and a webbed neck.

(iii) **Klinefelter's Syndrome** is caused by the presence of an extra copy of the X-chromosome in males, such as **44+XXY or 44+XXXY**. Despite having male characteristics, individuals with Klinefelter's Syndrome often exhibit underdeveloped testes, breast-like structures, limited facial and body hair growth, infertility due to a lack of sperm production, and mental retardation.

principles of inheritance and variation

Gregor Mendel

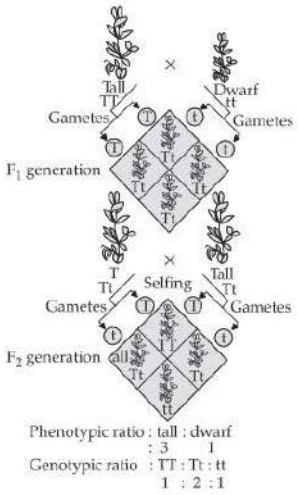
Proposed three laws

Law of Dominance

In heterozygous condition, only one member of a pair expresses itself and the hybrid is called as dominant while the manifestation of the other is masked and is known as recessive

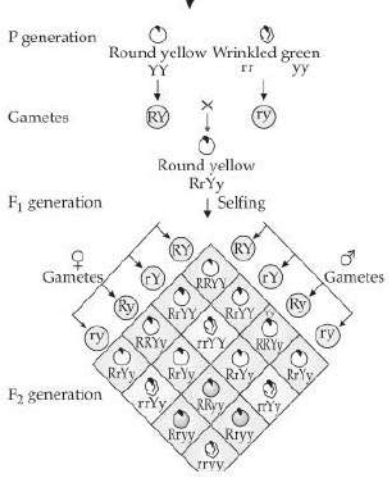
Law of Segregation

During gamete formation, the factors (alleles) of a character pair present in parents segregate from each other such that a gamete receives only one of the two factors.



Law of Independent assortment

When two pairs of traits are combined in a hybrid, segregation of one pair of characteristics is independent of the other pair of characters.



S.No.	Characters	Contrasting Traits
1.	Stem height	Tall/dwarf
2.	Flower colour	Violet/white
3.	Flower position	Axial/terminal
4.	Pod shape	Inflated/constricted
5.	Pod colour	Green/yellow
6.	Seed shape	Round/ wrinkled
7.	Seed colour	Yellow/green

Studied 7 Pairs of contrasting characters of pea plant

Genetic Disorders

Mendelian Disorders

These are caused by alteration or mutation in the single gene.
Autosomal dominant: e.g., Muscular dystrophy.
Autosomal recessive: e.g., Sickle cell anaemia, Albinism
Sex linked: e.g., Haemophilia.

Chromosomal Disorders

These are caused due to absence or excess or abnormal arrangement of one or more chromosomes.
Example, Down's syndrome (trisomy of 21).
Klinefelter's Syndrome (XXY in male).
Turner's syndrome (XO in female).

Sex Determination

- ZZ—ZW mechanism - Example: Birds
- XX—XO mechanism - Example: grasshopper
- XX–XY mechanism -Example: Human being

Chromosomal Theory of inheritance

- Proposed by Walter Sutton and Theodore Boveri in 1902.
- Thomas Hunt Morgan formulated chromosomal theory
- of inheritance using fruit flies *(Drosophila melanogaster)*.
- Morgan coined the term Linkage.

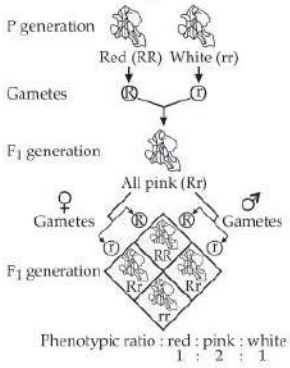
It States

- Chromosomes are immortal.
- Two identical chromosomes form a homologous pair.
- They segregate at the time of gamete formation.
- Independent pairs segregate independently of each other.
- Chromosomes are mutable.

Non-Mendelian Inheritance

Incomplete Dominance

The heterozygous offspring shows intermediate character between two parental characteristics.
Phenotypic ratio and Genotypic ratio are same. e.g., Flower colour in *Antirrhinum sp.* and *Mirabilis jalapa*.



Co-Dominance

Two alleles of a gene are equally dominant and express themselves even when they are together.
e.g., ABO blood grouping in human.

Multiple Alleles

A gene exists in more than two allelic forms e.g., ABO blood grouping

Pleiotropy

Ability of a gene to have multiple phenotypic effects as it influences a number of characters simultaneously.

Trace the Mind Map

First Level · Second Level · Third Level

Practice Questions

1.Which of the following statements best describes the branch of biology known as genetics?

a) Variation b) Inheritance c) Both (a) and (b) d) Study of characters

2.The tendency of offspring to differ from their parents is called

a) Variation b) Heredity c) Inheritance d) Resemblance

3.Mendel investigated characters in garden pea plant manifested in two traits which were

a) Similar b) Non-zygote c) Identical d) Opposite

4. A true breeding line is characterized by the presence of

a) Stable trait inheritance due to the continuous self-pollination

b) Varying traits in different generations due to the cross-pollination

c) Single trait in all generations due to allogamy

d) Varying trait inheritance in a single generation due to geitonogamy

5.Out of 7 contrasting trait pairs selected by Mendel, how many traits were dominant and recessive?

a) 7 and 7 b) 8 and 6 c) 6 and 8 d) 5 and 9

6.Which is correct about traits chosen by Mendel for his experiment on pea plant?

a) Terminal pod was dominant b) Constricted pod was dominant

c) Green colored pod was dominant d) Tall plants were recessive

7. The first hybrid progeny obtained by Mendel were called

a) F1 progeny b) F0 progeny c) F2 progeny d) F3 progeny

8.In a cross between a pure tall and a dwarf plant, what will be the phenotype of their offspring?

(a) Tall (b) Short (c) Intermediate (d) None of these

9.In Mendel's experiment, when did the recessive character of dwarfness appear?

(a) F1 (b) F2 (c) F3 (d) F2 and F3

10.How did Mendel obtain the recessive (dwarf) character in the F2 generation?

(a) By self-pollinating the F1 plants (b) By self-pollinating the F2 plants

C) By cross-pollinating the F1 plants (d) By cross-pollinating the F2 plants

11.When Mendel crossed tall and dwarf plants, both tall and dwarf plants were produced in the F2 generation. What does this show?

(a) Blending of characters (b) Atavism

c) Non-blending of characters (d) Intermediate characters

12.During his experiments, Mendel used the term "factor" for:

(a) Genes (b) Traits (c) Characters (d) Qualities

13.Which of the following is an incorrect match?

(a) Phenotype – Physical appearance of an organism

(b) Genotype – Expressed genes

c) Homozygous – Identical alleles of a gene present at the same locus

(d) Heterozygous – Genes of an allelic pair are not the same

14.What is the phenotypic ratio of a monohybrid cross in the F2 generation?

(a) 3:1 (b) 1:2:1 (c) 2:1:1 (d) 9:3:3:1

15.A man with blood group 'A' marries a woman with blood Group 'B'. The probability of their child having blood group 'O' is

(a) 25% (b) 50% (c) 75% (d) 0%

16.In humans, the inheritance of ABO blood group is an example of

(a) pleiotropy (b) multiple alleles (c) sex-linked inheritance (d) polygenic inheritance

17.A woman with blood group 'O' has a child with blood group 'AB'. Which of the following is possible for the father's blood group?

(a) A (b) B (c) AB (d) Any of the above

18.In humans, the inheritance of hemophilia is an example of

(a) sex-linked recessive inheritance (b) sex-linked dominant inheritance

(c) autosomal recessive inheritance (d) autosomal dominant inheritance

19.In pea plants, the inheritance of seed shape (round vs wrinkled) is an example of

(a) monohybrid cross (b) dihybrid cross

(c) test cross (d) back cross

20.Which of the following traits shows the law of dominance in inheritance?

(a) Seed color in pea (b) Flower color in Mirabilis jalapa

(c) Starch grain size in pea (d) Roan coat color in cattle

21.Which law states that characters do not blend and both are recovered in their original form in F2 generation, even if one of the characters is absent in the F1 progeny?

(a) Law of purity of gametes (b) Law of independent assortment

(c) Law of incomplete dominance (d) Law of dominance

22.In incomplete dominance, one allele functions as normal, while another allele may function as:

(a) Normal allele
(b) Non-functional allele
(c) Normal but less efficient allele
(d) All of the above

23.Which of the following is true about incomplete dominance and codominance?

(a) They have identical phenotypic ratios
(b) They have identical genotypic ratios
(c) Both (a) and (b)
(d) None of the above

24.The synthesis of starch in pea seeds is controlled by a single gene with two allelic forms B and b. Which of the following options is/are correct?

(a) BB produces round seeds with large starch synthesis

(b) bb produces wrinkled seeds with large starch synthesis

c) Bb produces round seeds with less starch synthesis

(d) All of the above

25.The types of gametes formed by the genotype RrYy are:

(a) RY, Ry, rY, ry
(b) RY, Ry, ry, ry
(c) Ry, Ry, Yy, ry
(d) Rr, RR, Yy, YY

26.In Mendel's experiments with garden pea, round seed shape (RR) was dominant over wrinkled seeds (rr) and yellow colour (YY) was dominant over green colour (yy). What are the expected phenotypes in the F1 generation of the cross RRYY x rryy?

(a) Only round seeds with yellow cotyledons

(b) Only wrinkled seeds with yellow cotyledons

c) Only wrinkled seeds with green cotyledons

(d) Round seeds with yellow cotyledons and wrinkled seeds with yellow cotyledons

27. In a cross between pure breeding pea plants having yellow round (YYRR) and green wrinkled (yyrr) seeds, find out the total number of seeds (plants) having yellow color in F2 generation.

(a) 12 (b) 10 (c) 14 (d) 11

28. In a cross between plants having yellow round (YYRR) and green wrinkled (yyrr) seeds, what will be the ratio between seeds having yellow and green seed color?

(a) 3:2 (b) 3:1 (c) 9:7 (d) 7:9

29.Mendel's results on inheritance of characters were rediscovered by:

(a) de Vries (b) Correns (c) von Tschermak (d) All of these

30.Which of the following statements is true about polygenic traits?

(a) They are controlled by a single gene

(b) They are controlled by two genes

(c) They are controlled by three or more genes

(d) They are controlled by mutant genes

31.Which of the following statements is true about Phenylketonuria (PKU) in humans?

(a) It manifests through phenotypic expressions

(b) It is characterized by mental retardation

(c) It leads to hair reduction and skin pigmentation

(d) All of the above

32.Which of the following pairs is incorrectly matched?

(a) XO type of sex-determination – Grasshopper

(b) ABO blood grouping – Codominance

(c) Starch synthesis in pea – Multiple allele

(d) TH Morgan – Linkage

33.Which of the following pairs is incorrectly matched with respect to sex determination in different organisms?

(a) Grasshopper = XO type

(b) Birds = ZZ-ZW type

(c) Drosophila = XX-XO type

(d) Human = XX-XY type

34.What is the karyotype of a human male and female?

(a) Male = 44 + XX, Female = 44 + XY

(b) Male = 44 + XY, Female = 44 + XX

(c) Male = 44 + XO, Female = 44 + XX

(d) Male = 44 + XX, Female = 44 + XO

35.If there are four different types of nitrogenous bases (A, T, G, and C), how many different types of transitions and transversions are possible?

(a) Transition = 8, Transversion = 4

(b) Transition = 4, Transversion = 4

(C) Transition = 8, Transversion = 4

(d) Transition = 4, Transversion = 8

36.What type of mutation is responsible for sickle-cell anemia?

(a) Frame-shift mutation

(b) Point mutation

(c) Both (a) and (b)

(d) None of the above

37.What is the cause of colour blindness in humans?

(a) Defect in either red or green cone of eyes

(b) Mutation in a gene found on the X-chromosome

(c) Affects males more frequently than females

(d) All of the above

38.In haemophilia, the affected protein is part of a cascade of proteins that are involved in the:

(a) Formation of RBCs

(b) Formation of WBCs and platelets

c) Coagulation of blood

(d) Anticoagulation

39.How is sickle-cell anemia inherited?

(a) Both parents are heterozygous carriers but are unaffected

(b) Single pair of allele controls the disease

(c) Only Hb^{s} Hb^{s} show diseased phenotype

(d) All of the above

40.What is the cause of thalassemia in humans?

(a) An autosomal recessive blood disorder

(b) Transmission from parents to offspring when both parents are unaffected carriers (heterozygous)

(c) Mutation or deletion of one of the alpha or beta-globin chains

(d) All of the above

41.Which of the following is an example of a dominant trait?

a) blue eyes b) Freckles c) Straight hair d) Widow's peak

42.What is the probability of producing a child with sickle cell disease if both parents are carriers?

a) 0% b) 25% c) 50% d) 75%

43.In a pedigree chart, what does a filled-in circle represent?

a) A male who carries a particular trait

b) A female who does not carry a particular trait

c) A female who carries a particular trait

d) A male who does not carry a particular trait

44.Which of the following best describes the process of meiosis?

a) A cell divides into two identical daughter cells

b) Two cells fuse to form a single daughter cell

c) A cell divides twice to produce four haploid daughter cells

d) A cell replicates its DNA to produce two identical daughter cells

45.What is the function of mRNA in protein synthesis?

a) It carries amino acids to the ribosome

b) It holds the ribosome in place during translation

c) It serves as a template for the synthesis of a protein

d) It helps to break down the mRNA molecule after translation is complete

46.Which of the following best describes a point mutation?

a) A change in the number of chromosomes

b) A change in the sequence of DNA bases

c) A change in the structure of a chromosome

d) A change in the function of a protein

47.Which of the following is an example of a phenotype?

a) The sequence of bases in a DNA molecule

b) The color of a flower

c) The ratio of dominant to recessive alleles in a population

d) The frequency of a particular gene in a family

48.Which of the following best describes genetic drift?

a) The transfer of genes between populations

b) The introduction of new alleles into a population

c) The random fluctuation of allele frequencies in a small population

d) The selection of particular traits in a population due to environmental factors

49.What is the difference between a gene and an allele?

a) A gene is a section of DNA that codes for a protein, while an allele is a variant form of a gene

b) A gene is a physical structure, while an allele is an abstract concept

c) A gene is always dominant, while an allele can be dominant or recessive

d) A gene is inherited from one parent, while an allele is inherited from both parents

50.Which of the following best describes a mutation?

a) A change in the frequency of alleles in a population over time

b) A change in the phenotype of an individual due to environmental factors

c) A change in the sequence of DNA bases that affects the function of a protein

d) A change in the behavior of an organism due to learned experiences

Answers

1.Answer: Option © Both (a) and (b)

Explanation: Genetics is a branch of biology that deals with the study of heredity and variation of inherited traits in organisms. It includes the study of genes, their function, and the way they are passed down from one generation to another. Therefore, option © is the correct answer.

2. Answer: Option (a) Variation

Explanation: Variation refers to the differences that can exist between the characteristics of offspring and their parents. These differences can be due to genetic or environmental factors. Therefore, option (a) is the correct answer.

3.Answer: Option (d) Opposite

Explanation: Mendel investigated garden pea plants and identified two traits that were contrasting or opposite to each other, such as tall and short, yellow and green seed color, round and wrinkled seeds. Therefore, option (d) is the correct answer.

4.Answer: Option (a) Stable trait inheritance due to the continuous self-pollination

Explanation: A true breeding line is a group of organisms that are homozygous for a particular trait and when they are crossed with each other, they produce offspring that are also homozygous for that trait. This is possible due to the continuous self-pollination of the plants. Therefore, option (a) is the correct answer.

5.Answer: Option © 6 and 8

Explanation: Mendel selected 7 pairs of contrasting traits, such as tall and short, round and wrinkled seeds, etc., and found that 6 of them were dominant while the remaining 2 were recessive. Therefore, option © is the correct answer.

6.Answer: Option (a) Terminal pod was dominant

Explanation: Mendel chose seven pairs of contrasting traits to study in pea plants, and terminal pod and axial pod were one such pair. He found that the trait of terminal pod was dominant over the axial pod. Therefore, option (a) is the correct answer.

7.Answer: Option (a) F1 progeny

Explanation: When Mendel crossed two purebred pea plants with different traits, the first generation

8. Answer: (a) Tall. According to Mendel's laws of inheritance, if one parent is pure dominant (TT) for a trait and the other parent is recessive (tt) for the same trait, all of the offspring in the F1 generation will be heterozygous (Tt) and will exhibit the dominant trait. In this case, the dominant trait is tallness.

9.Answer: (a) F1. When Mendel crossed a true-breeding tall plant with a true-breeding dwarf plant, all of the F1 offspring were tall. The dwarf trait did not appear in this generation because it was recessive and masked by the dominant tall trait.

10.Answer: (a) By self-pollinating the F1 plants. When Mendel self-pollinated the F1 generation, he found that the dwarf trait appeared in the F2 generation in a ratio of 1:3, with one dwarf plant for every three tall plants.

11. Answer: © non-blending of characters. This is because the F2 generation showed a clear separation of the two traits, with some plants being tall and others being dwarf, rather than all being intermediate or a blend of the two.

12. Answer: (a) Genes. Mendel used the term "factors" to refer to the units of inheritance that are responsible for the expression of traits.

13. Answer: (b) Genotype – Expressed genes. Genotype refers to the genetic makeup of an organism, including both expressed and unexpressed genes. Phenotype refers to the observable physical or biochemical traits of an organism.

14.Answer: (b) 1:2:1. In a monohybrid cross, where only one trait is being studied, the phenotypic ratio in the F2 generation is 1:2:1. This means that for every three offspring, one will show the homozygous dominant phenotype, two will show the heterozygous phenotype, and one homozygous recessive.

15.Answer: (d) 0%

Explanation: If a man with blood group 'A' marries a woman with blood group 'B', their child can only have blood group 'AB', 'A', 'B', or 'O'. Therefore, the probability of their child having blood group 'O' is 0%.

16.Answer: (b) multiple alleles

Explanation: The inheritance of ABO blood group in humans is controlled by multiple alleles, where three alleles (IA, IB, and i) determine the four blood types (A, B, AB, and O).

17.Answer: (d) Any of the above

Explanation: The mother has blood group 'O', which means she can only pass on the 'i' allele. The child has blood group 'AB', which means the child has the IA and IB alleles. Therefore, the father could have blood group 'A' (IAi), 'B' (IBi), or 'AB' (IAIB).

18.Answer: (a) sex-linked recessive inheritance

Explanation: Hemophilia is a sex-linked recessive disorder, which means the gene for the disorder is located on the X chromosome. Males are more likely to inherit the disorder because they only have one X chromosome, while females have two X chromosomes and would need to inherit two copies of the gene to express the disorder.

19.answer: (a) monohybrid cross

Explanation: The inheritance of seed shape in pea plants involves only one gene and is therefore an example of a monohybrid cross. The gene for seed shape has two alleles, with round being dominant over wrinkled.

20.Explanation: The law of dominance states that one allele (the dominant allele) is expressed over the other allele (the recessive allele) in a heterozygous individual. This is seen in the inheritance of seed color in pea plants, where the dominant allele for round seed shape is expressed over the recessive allele for wrinkled seed shape.

21. Answer: (d) Law of dominance

Explanation: The Law of dominance states that when two alleles are crossed, one allele (the dominant allele) will be expressed over the other (the recessive allele) in a heterozygous individual. This is why both characters are recovered in their original form in the F2 generation, even if one of the characters was absent in the F1 progeny.

22.Answer: © Normal but less efficient allele

Explanation: In incomplete dominance, the phenotype of the heterozygous individual is a blending of the phenotypes of the two homozygous parents. One allele function normally, but the other allele is less efficient, resulting in an intermediate phenotype.

23.Answer: (a) They have identical phenotypic ratios

Explanation: Incomplete dominance and codominance are similar in that they both result in a 1:2:1 phenotypic ratio when two heterozygous individuals are crossed. However, they differ in that in codominance, both alleles are fully expressed, while in incomplete dominance, the phenotype is a blending of the two alleles.

24. Explanation: Option (a) is correct because BB produces round seeds with large starch synthesis.

25. Explanation: Each parent produces two types of gametes (Ry and rY from Rr and Yy and yY from Yy), so the possible gametes from the genotype RrYy are RY, rY, Ry, ry in equal proportions. Therefore, the correct answer is (a).

26. Explanation: The F1 generation will be RrYy, which means that all of the offspring will have round seeds and yellow cotyledons, so the correct answer is (a).

27 Explanation: The F2 generation will have a ratio of 9:3:3:1 for round yellow, round green, wrinkled yellow, and wrinkled green seeds respectively. This means that out of 16 seeds, 12 will have yellow color, so the correct answer is (a).

28. Explanation: The ratio of seeds having yellow to green color will be 3:1, so the correct answer is (b).

29. Explanation: Mendel's results on inheritance of characters were independently rediscovered by de Vries, Correns, and von Tschermak, so the correct answer is (d).

30.Answer: © Polygenic traits are controlled by multiple genes, often from different loci, and each gene contributes a small amount to the phenotype. Examples of polygenic traits include height, skin color, and intelligence.

31.Answer: (d) PKU is a genetic disorder that results in the inability to break down the amino acid phenylalanine, leading to a buildup of this substance in the body. This can cause mental retardation, behavioral problems, seizures, and other symptoms. These phenotypic expressions can also lead to hair reduction and skin pigmentation.

32.Answer: (b) ABO blood grouping is not an example of codominance, but rather multiple allelism. Codominance occurs when both alleles in a heterozygous individual are expressed equally, while multiple allelism refers to the presence of more than two alleles at a particular locus.

33.Answer: © Drosophila has a different sex determination system, where females have two X chromosomes (XX) and males have one X and one Y chromosome (XY).

34. answer is (b) Male = 44 + XY, Female = 44 + XX.Humans have 23 pairs of chromosomes, of which 22 pairs are autosomes and one pair is sex chromosomes. Females have two X chromosomes, denoted as XX, while males have one X and one Y chromosome, denoted as XY. Therefore, the karyotype of a human male is 44 autosomes and one X and one Y chromosome, or 44 + XY, and the karyotype of a human female is 44 autosomes and two X chromosomes, or 44 + XX

35.Answer: (b) A transition occurs when a purine (A or G) is substituted for another purine, or when a pyrimidine (C or T) is substituted for another pyrimidine. A transversion occurs when a purine is substituted for a pyrimidine, or vice versa. With four nitrogenous bases, there are four possible transitions and four possible transversions.

36.Answer: (b) Point mutation

Explanation: Sickle-cell anemia is caused by a point mutation in the beta-globin gene, which results in the substitution of valine for glutamic acid at position 6 in the beta-globin chain of hemoglobin.

37.Answer: (d) All of the above

Explanation: Colour blindness is caused by a mutation in a gene found on the X-chromosome that encodes photopigments in the red and green cone cells of the retina. This can result in a defect in either the red or green cone cells of the eyes, and since the gene is located on the X-chromosome, males are more frequently affected than females.

38.Answer: © Coagulation of blood

Explanation: Haemophilia is a genetic disorder caused by a deficiency of clotting factors VIII or IX, which are part of the coagulation cascade of proteins involved in the clotting of blood. The deficiency can result in prolonged bleeding and can be life-threatening in severe cases.

39.Answer: (a) Both parents are heterozygous carriers but are unaffected

Explanation: Sickle-cell anemia is an autosomal recessive disorder, which means that it is caused by a mutation in both copies of the beta-globin gene. Individuals who are heterozygous carriers have one normal and one mutated copy of the gene, and they do not exhibit the disease phenotype. However, when two carriers have children, there is a 25% chance that their offspring will inherit two mutated copies of the gene and will develop sickle-cell anemia.

40.Answer: (d) All of the above

Explanation: Thalassemia is caused by mutations or deletions in one of the alpha or beta-globin chains that make up hemoglobin. It is an autosomal recessive disorder that can be transmitted from unaffected carriers (heterozygous) parents to their offspring. The severity of the disease depends on the extent of the mutation or deletion, and it can affect the production of red blood cells, leading to anemia

41.c) Straight hair is an example of a dominant trait. In genetics, a dominant trait is one that only requires one copy of the gene for it to be expressed. Straight hair is a dominant trait, which means that if an individual has even one copy of the gene for straight hair, they will have straight hair.

42.b) 25% is the probability of producing a child with sickle cell disease if both parents are carriers. Sickle cell disease is caused by a recessive gene, which means that an individual needs two copies of the gene (one from each parent) to express the disease. If both parents are carriers, then each of their children has a 25% chance of inheriting two copies of the sickle cell gene and developing sickle cell disease.

43.c) A filled-in circle on a pedigree chart represents a female who carries a particular trait. A pedigree chart is a diagram that shows the inheritance of a particular trait within a family over multiple generations. Filled-in circles represent females, while unfilled circles represent males. A filled-in circle indicates that the female carries the trait being studied, whether it is dominant or recessive.

44.c) Meiosis is the process of cell division that produces four haploid daughter cells. During meiosis, a cell divides twice, resulting in the formation of four daughter cells. Each of these daughter cells contains only half the number of chromosomes as the original cell. This is important in sexual reproduction because it ensures that each gamete (sperm or egg) only contains one copy of each chromosome, which is necessary for the formation of a diploid zygote during fertilization.

45.c) mRNA serves as a template for the synthesis of a protein during protein synthesis. The process of protein synthesis involves the production of proteins from the genetic information contained in DNA. mRNA, or messenger RNA, is transcribed from DNA and carries the genetic information from the nucleus to the ribosome, where it is translated into a specific sequence of amino acids that make up a protein.

46.b) A point mutation is a change in the sequence of DNA bases. A point mutation occurs when a single nucleotide base is added, deleted, or replaced in a DNA sequence. This can result in a change in the amino acid sequence of a protein, which can affect its function. Point mutations can be silent, meaning they do not change the resulting protein, or they can be missense or nonsense mutations, which result in a different amino acid or a premature stop codon, respectively.

47.b) The color of a flower is an example of a phenotype. A phenotype is the observable physical or biochemical characteristics of an organism that are determined by its genotype and environmental factors. In the case of a flower, its color is determined by the expression of certain genes, as well as environmental factors such as light and temperature.

48.c) Genetic drift is the random fluctuation of allele frequencies in a small population. Genetic drift refers to the random changes in allele frequencies that can occur in a small population due to chance events such as genetic mutations, migrations, or natural disasters. This can lead to a loss of genetic diversity in a population and can increase the likelihood of genetic disorders.

49.a) A gene is a section of DNA that codes for a protein, while an allele is a variant form of a gene. Genes are segments of DNA that contain the instructions for making a specific protein, while alleles are different versions of the same gene. For example, the gene that determines eye color may have several different alleles, such as one for blue eyes and one for brown eyes.

50.c) A mutation is a change in the sequence of DNA bases that affects the function of a protein