HEREDITY AND EVOLUTION

TOPIC 1

ACCUMULATION OF VARIATION DURING REPRODUCTION

Heredity can be defined as resemblances among individuals related by descent or the transmission of traits from parents to the offsprings. It means continuity of features from one generation to the next. Variation is defined as the occurrence of differences in the characters (or traits) among the individuals. In a number of sexually reproducing animals, including human beings, quite distinct variations are visible among different individuals. The long term accumulation of variations may lead to gradual changes in the form or functions of organisms and may even lead to the formation of a new species over time. This process is known as evolution.

In case an organism reproduces by asexual reproduction, one organism gives rise to two individuals which are similar in body design, but having subtle differences. These will in turn give rise to two individuals in the next generation. In this way, the four individuals formed will be different from each other.

If sexual reproduction is involved, greater diversity will be generated in the offsprings as compared to asexual reproduction where only minor differences would be generated due to small inaccuracies in DNA copying. Depending on the nature of variations, different individuals would have different kinds of advantages. Selection of variants by environmental factors forms the basis for evolutionary processes.

MOST LIKELY Questions

Short Answer Type-II Questions (SA-II)

[3 marks]

1. **Newly formed DNA copies may not be identical at times. Give reason.**

Ans. The replication of DNA in the cell is done by biochemical reactions. No biochemical reaction can reproduce exactly the same result. So, when the DNA present in the nucleus of the parent cell undergoes replication, then slight variations occur in the two DNA copies formed. Due to this, the two DNA molecules formed will be similar but may not be exactly identical to the parent DNA.

These variations in the replication of DNA molecule will also lead to slight variations in the offspring produced by asexual reproduction.

TOPIC 2

HEREDITY

Genetics is the branch of biology which studies heredity and variation. Inheritance is the transmission of genetically controlled traits from one generation to the next.

Inherited Traits

The traits or characteristics that are transmitted from one generation to the next are controlled by genes. A gene is a segment of DNA which is responsible for the synthesis of proteins that contains a specific character of the organism. An example is the free earlobes and attached earlobes found in human population.

Mendel's Contributions

Gregor Mendel was the first scientist to make a systematic study of patterns of inheritance which involved the transfer of characteristics from parents to progeny (offsprings). He is known as the Father of Genetics.

Mendel's Experiment

Mendel used a number of contrasting visible characters of garden peas – round/wrinkled seeds, tall/short plants, white/violet flowers and so on. He took pea plants with different characteristics – a tall plant and a short plant, produced progeny from them, and calculated the percentages of tall or short progeny. Mendel chose pea plants for studying inheritance because pea plants had a number of distinct differences which were easy to tell apart.

(1) Availability of detectable contrasting traits of several characters.

(2) Short life span of the plant.

(3) Normally allows self-fertilisation but cross-fertilisation can also be carried out.

(4) Large number of seeds produced.

Monohybrid inheritance:

(1) It concerns the inheritance of a single plant characteristic such as plant height or colour of flowers.

(2) Mendel first crossed pure-bred tall pea plants with pure-bred dwarf pea plants and found that there were no halfway characteristics or 'medium-height' plants in this first generation, or F_1 progeny. All plants were tall.

(3) Mendel then crossed the tall pea plants of the first generation by self pollination and found that the second-generation, or F_2, progeny of the F_1 tall plants are not all tall. Instead, one quarter of them were short.

(4) Both the tallness and shortness traits were inherited in the F_1 plants, but only the tallness trait was expressed.

(5) Two copies of the trait are inherited in each sexually reproducing organism. These two may be identical, or may be different, depending on the parentage.

(6) Out of a total 1064 pea plants of F_2 generation, Mendel found that there were 787 tall pea plants and 277 dwarf pea plants. The ratio of tall plants to dwarf plants comes to be approximately 3 : 1. The ratio 3 : 1 is known as the monohybrid ratio.

e.g., The genotypic ratio of F_2 progeny is TT : Tt : tt = 1 : 2 : 1.

Dihybrid inheritance:

(1) It concerns the inheritance of characteristics when pea plants showing two different characteristics, rather than just one, are bred with each other.

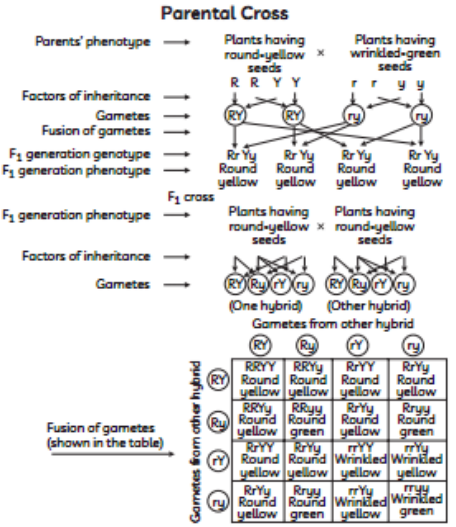
(2) The progeny of a tall plant with round seeds and a short plant with wrinkled-seeds are all tall and have round seeds. Tallness and round seeds are thus dominant traits.

(3) When these F_1 progeny are used to generate F_2 progeny by self-pollination, some F_2 progeny are tall plants with round seeds, and some were short plants with wrinkled seeds.

(4) There would also be some F_2 progeny that showed new mixtures. Some of them would be tall, but have wrinkled seeds, while others would be short, but have round seeds.

(5) The tall/short trait and the round seed/wrinkled seed trait are independently inherited.

Independent Inheritance of two separate traits: In the inheritance of more than one pair of traits in a cross simultaneously, the factors responsible for each pair of traits are distributed independently to the gametes. The dihybrid cross can be shown by drawing a chart as shown:



Important Terms used in Heredity

Chromosome: Chromosomes are the carriers of genes and are long thread like structures present in the nucleus of a cell. Each gene set is present as separate independent pieces, each called a chromosome.

DNA: Cellular DNA is the information source for making proteins in the cell. DNA is the genetic material. DNA is the carrier of genetic information from generation to generation. Every chromosome contains one molecule of DNA and genes are segments of DNA.

Genes: Gene is a segment of a large molecule called deoxyribonucleic acid (DNA) which forms the most important constituent of chromosome. Genes are located on the chromosomes at fixed positions and their number is estimated to be between 30, 000 to 40, 000. Genes control characteristics or traits.

Allele: One of the different forms of a particular gene occupying the same position on a chromosome.

Factor: The carriers of hereditary information were called as factors by Mendel. He considered each and every character as a unit, which was controlled by a 'factor' based on his experiments with garden pea.

F_1 generation: When two parents cross or breed to produce progeny, then their progeny is called first filial generation.

F_2 generation: When the first generation progeny cross among themselves to produce second progeny,

then this progeny is called second filial generation.

Diploid: The paired condition of chromosomes is called diploid. The diploid number of chromosomes is specific for a species and every cell has diploid number of chromosomes.

Haploid: It is the set of unpaired chromosomes. Gametes have haploid set of chromosomes.

Homologous chromosome: Members of a pair of chromosomes are exactly identical as far as shape and size are concerned and hence called homologous chromosomes.

Genotype: It is the description of genes present in an organism. It is always a pair of letters such as TT, Tt or tt (where T and t are the different forms of the same gene).

Phenotype: The characteristic or trait which is visible in an organism is called its phenotype. Being tall or dwarf are phenotypes of a plant as these traits are visible.

Dominant and recessive traits: In this explanation, both TT and Tt are tall plants, while only tt is a short plant. In other words, a single copy of 'T' is enough to make the plant tall, while both copies have to be 't' for the plant to be short. So, a tall plant will have genotype TT or Tt, whereas a short plant will have genotype tt. Traits like 'T' are called dominant traits or expressed traits, while those that behave like 't' are called recessive traits or repressed traits.

Mendel's Laws of Inheritance

Law	Definition
Law of Segregation	During gamete formation, the alleles for each gene segregate from each other so that each gamete carries only one allele for each gene.
Law of Independent Assortment	Genes for different traits can segregate independently during the formation of gametes.
Law of Dominance	Some alleles are dominant while others are recessive; an organism with at least one dominant allele will display the effect of the dominant allele.

Expression of Traits

Genes control characteristics or traits in all organisms. Cellular DNA is the information source for making proteins in the cell. Each trait is governed by a particular hormone and the amount of the hormone made depends on the efficiency of the process for making it which in turn depends on a particular enzyme that is important for this process. If this enzyme works efficiently, a lot of hormone will be made and if the gene for that enzyme has an alteration that makes the enzyme less efficient, the amount of hormone will be less.

Mechanism of Inheritance

The rules for inheritance of traits in sexually reproducing organisms are related to the fact that both the parents contribute practically equal amounts of genetic material to the offspring. This means that each trait can be influenced by both paternal and maternal DNA. Thus, for each trait there will be two versions in each offspring.

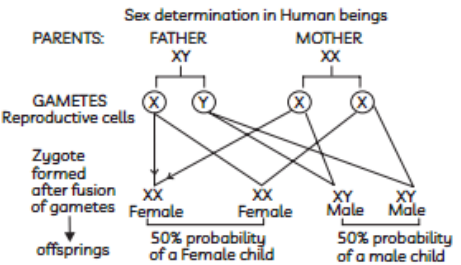
Every germ cell takes one chromosome from each pair and these may be of maternal or parental origin. When two germ cells combine, they will restore the normal number of chromosomes in the progeny and in this way the DNA of the species becomes stable.

Sex Determination

In human beings, the sex of the offspring in the zygote after fertilization of the male and female gamete is determined by the sex chromosome. The rest of the chromosomes are called autosomes. Human beings have 22 pairs of autosomes and one pair of sex chromosome. The females carry two X- chromosomes but the males carry a single X and a Y chromosome. Among the male gametes, half of the sperms carry X-chromosome and half carry Y-chromosome. In human beings, the sex of the individual is largely genetically determined.

(1) When a sperm carrying X-chromosome fertilizes an egg, the zygote develops into female (XX).

(2) When a sperm carrying Y-chromosome fertilizes an egg, the zygote develops into male (XY).



Effect of environmental factors on sex determination:

In some reptiles, the temperature at which the fertilized egg is incubated before hatching is important for sex determination.

(1) In a turtle high incubation temperature results in development of female progeny.

(2) In the case of lizard, high incubation temperature results in development of male progeny.

MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

2. If a pure tall pea plant is crossed with a pure dwarf pea plant, then in F_1 generation only tall plants appear. What happens to the traits of the dwarf plant?

Ans. Although in F_1 generation only the tall plants appear, both the tallness and dwarfness traits are inherited in the F_1 plants but as the tallness trait is dominant, it is expressed, whereas, dwarfness trait being recessive is not expressed. It is expressed in F_2 generation.

3. (A) Why did Mendel carry out an experiment to study inheritance of two traits in garden-pea?

(B) What were his findings with respect to inheritance of traits in F_1 and F_2 generation?

(C) State the ratio obtained in the F_2 generation in the above mentioned experiment.

Ans. (A) Mendel carried out an experiment to study inheritance of two traits in garden pea to see the interaction and basis of inheritance between them. He also concluded that also traits segregate during gamete formation and finally he gave three laws.

(1) Law of segregation

(2) Law of Dominance

(3) Law of Independent Assortment

(B) Mendel observed that—In F_1 generation, feature of only one parental type appear. The features of other parents were not expressed. He called the first one which appeared as dominant features/character and the other features which did not appear called them as recessive.

The characters are not lost even when they are not expressed.

When F_1 off springs were allowed to be self pollinated, both the parental traits were expressed in definite proportion in F_2 generation.

He had started with two combinations of characteristics and two new combinations of characteristics appeared in F_2 generation.

From the F_2 generation of a dihybrid cross Mendel postulated that inheritance of factors which control a particular trait in an organism are independent of the other. This is called law of Independent Assortment.

(C) Ratio obtained in the F_2 generation in the above mentioned experiment

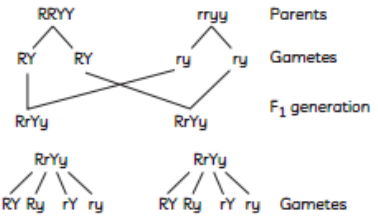
9 : 3 : 3 : 1

Explanation: *r* = Round

w = wrinkled

y = yellow

g = green



	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

F_2 generation:

Plants with round and yellow coloured seeds		Plants with round and green coloured seeds		Plants with wrinkled and yellow coloured seed		Plants with wrinkled and green coloured seeds
9	:	3	:	3	:	1

4. In a study it was found that fused ear lobes were found in more numbers within a population rather than free ear lobes. What can you infer from the above observation with respect to dominant/recessive trait?

Ans. It can be inferred from the observation that fused ear lobes were found in more numbers within a population that fused ear lobes is a dominant trait whereas free ear lobes is a recessive trait.

5. Mention the function of cellular DNA. Taking tallness as a characteristic for a plant, explain how proteins control the characteristic.

Ans. The major function of the DNA is to store information and pass it to offspring. It also directs the synthesis of proteins, which are necessary for a cell to perform its functions. The part of DNA that provides information for protein synthesis is called gene. Proteins control specific characteristic or trait of an organism.

For example, a plant species has gene for the characteristic called 'tallness'. Now, the gene for tallness will give orders to the plant cells to make a lot of plant growth hormones. Due to the formation of excess of plant growth hormones, the plant will grow tall.

If the plant has genes for dwarfness, then plant growth hormones production will be low. As a result, the plant will not grow tall and will remain short. The above examples explain how proteins control the characteristic.

Case Based Questions

[4 marks]

6. *Sahil performed an experiment to study the inheritance pattern of genes. He crossed tall pea plants (TT) with short pea plants (tt) and obtained all tall plants in F_1 generation.*

(A) What will be set of genes present in the F_1 generation?

(B) Give reason why only tall plants are observed in F_1 progeny.

(C) When F_1 plants were self - pollinated, a total of 800 plants were produced. How many of these would be tall, medium height or short plants? Give the genotype of F_2 generation.

Ans. (A) Tt

(B) Traits like 'T' are called dominant traits, while those that behave like 't' are called recessive traits./Alternatively accept the definition of dominant and recessive traits with examples of T and t respectively / Alternatively accept the law of Dominance with examples of T and t.

(C) Out of 800 plants 600 plants will be tall and 200 plants will be small 1 TT : 2Tt : 1tt

Concept Applied

➥ *Cross between the pea plants with one pair of contrasting characters is called a monohybrid cross. Here the contrasting character are tallness and shortness of pea plants.*

Monohybrid cross

Parents Tall plant TT × Short plant tt

Gametes T, T, t, t

F_1 generation Tt All tall plants

The set of genes in the F_1 generation is Tt. The F_1 generation possess one factor of inheritance from each parent plant which was carried in gametes and is dominant trait. Since all the plants in the F_1 generation have the factors Tt, so all of them are tall. When F_1 progeny was allowed to be self pollinated, both the parental traits were expressed in definite proportion in F_2 generation.

Self Pollination of F_1 generation Tt × Tt

Gametes T, t, T, t

F_2 generation

	T	t
T	TT Tall	Tt Tall
t	Tt Tall	tt Short

Pheno typic ratio 3 : 1

600 Tall 3

200 Short 1

800 4

Genotypic ratio 1 : 2 : 1

T T : Tt : tt

7. *X-linked recessive inheritance is a mode of inheritance in which a mutation in a gene on the X chromosome causes the phenotype to be always expressed in males (who are necessarily homozygous for the gene mutation because they have one X and one Y chromosome) and in females who are homozygous for the gene mutation. Females with one copy of the mutated gene are carriers. X-linked inheritance means that the gene causing the trait or the disorder is located on the X chromosome.*

In humans, inheritance of X-linked recessive traits follows a unique pattern as shown below:

5. Mention the function of cellular DNA. Taking tallness as a characteristic for a plant, explain how proteins control the characteristic.

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Gametes T, t, T, t

F_2 generation

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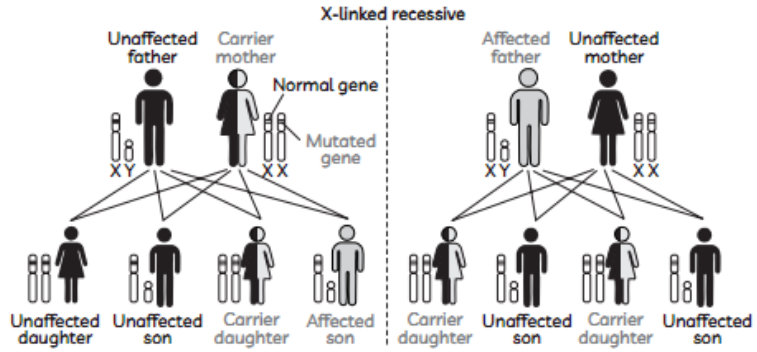
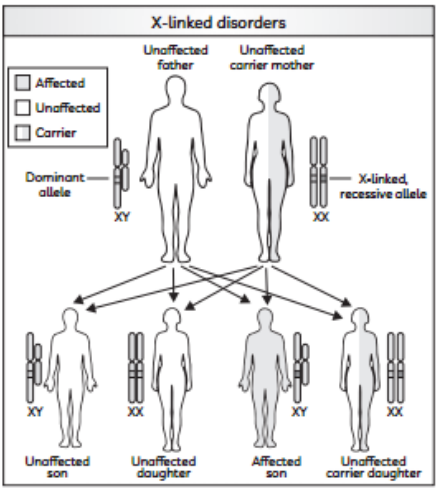




(A) Why are X-linked recessive traits are more commonly expressed in males than females?

(B) Insects also follow an XY sex-determination pattern and like humans, Drosophila males have an XY chromosome pair and females are XX. Eye color in Drosophila was one of the first X-linked traits to be identified. In fruit flies, the wild-type eye colour is red (XW) and is dominant to white eye colour (Xw).

In a cross between a white-eyed female fruit fly and red-eyed male, what percent of the female offspring will have white eyes? (White eyes are X-linked, recessive)

(C) In the cross shown above, if the father is unaffected and mother is also unaffected, but mother is a carrier (X-linked recessive allele present), What are your observations about their children.

Ans. (A) X-linked recessive traits are more commonly expressed in males than females. This is due to the fact that males possess only a single X chromosome, and therefore require only one mutated X in order to be affected.

Explanation: All daughters of an affected man will obtain his mutated X, and will then be either carriers or affected themselves depending on the mother. The resulting sons will either have a 50% chance of being affected (mother is carrier), or 100% chance (mother is affected). It is because of these percentages that we see males more commonly affected than females.

(B) The genotype of a white-eyed female fruit fly will be X^wX^w and of red eyed male will be X^WY. When we cross them, the genotype of offsprings will be:

X^wX^W (Red eyed female), X^wY (White eyed male), X^wX^W (Red eyed female) and X^wY (white eyed male).

All of the females are thus red-eyed and heterozygous. All of the males are white-eyed and hemizygous.

(C) Females have two X chromosomes while males have one X and one Y chromosome. Carrier females who have only one copy of the mutation do not usually express the phenotype. So, the son who receives the X chromosome containing the dominant allele will be unaffected whereas the son who receives X chromosome containing the recessive allele will be affected. Both daughters will be unaffected, but the daughter who receives the recessive allele from her mother will be carrier.

This means that males affected by an x-linked recessive disorder inherited the responsible X chromosome from their mothers.

Women possess two X chromosomes, and thus must receive two of the mutated recessive X chromosomes (one from each parent). A popular example showing this pattern of inheritance is that of the descendants of Queen Victoria and the blood disease hemophilia.

TOPIC 3

EVOLUTION

We have seen that there is an inbuilt tendency to variation during reproduction, both because of errors in DNA copying and as a result of sexual reproduction.

(1) A rare variation can become a common characteristic in a population when the frequency of an inherited trait changes over generations. Since genes control traits, we can say that the frequency of certain genes in a population changed over generations. This is the essence of the idea of evolution.

(2) A particular variation may become common if it gives survival advantage to the population. This is known as Natural selection which can direct evolution in a population. It results in adaptations in the population to fit their environment better.

(3) Accidents in small populations can change the frequency of some genes in a population, even if they give no survival advantage. This is the notion of genetic drift, which provides diversity without any adaptations.

Acquired and Inherited Traits

Acquired Trait is a phenotypic characteristic, acquired during growth and development, that is not genetically based and therefore cannot be passed on to the next generation (for example, the large muscles of a weight lifter).

For evolution to take place, there must be changes in the DNA of the germ cell. Change in non-reproductive tissues cannot be passed on to the DNA of the germ cells. Therefore the experiences of an individual during its lifetime cannot be passed on to its progeny, and cannot direct evolution.

Example: If we breed a group of mice, all their progeny will have tails, as expected. Now, if the tails of these mice are removed by surgery in each generation, then these tailless mice do not produce tailless progeny because removal of the tail cannot change the genes of the germ cells of the mice.

Differences between acquired traits and inherited traits:

S. No.	Acquired Traits	Inherited Traits
(1)	These traits or characteristics are not transmitted from one generation to the next	These traits are transmitted from parents to their progeny.
(2)	These traits do not bring about any changes in the germ cells or DNA as these are changes in non-reproductive tissues.	Genes of inherited traits are present in the germ cells or DNA
(3)	These cannot direct evolution as these are experiences of an individual acquired during its lifetime.	These may direct evolution as these bring about changes in the germ cells or DNA.
	Example: Acquiring a new hair style	Example: Hair texture

MOST LIKELY Questions

Short Answer Type-II Questions (SA-II)

[3 marks]

8. (A) "The reduction in the weight of an organism due to starvation is not genetically controlled." Comment on this statement.

(B) When does the formation of new species occur?

Ans. (A) The reduction in the weight of an organism due to starvation is not genetically controlled as it will not change the DNA of the germ cell. It is an environmentally

determined factor. Weight loss or gain occurs due to external factors such as food and is not genetically controlled. Hence, low weight parents can have heavy weight progeny due to difference in food habit.

(B) New species may be formed if DNA undergoes significant changes in germ cells and the chromosome number changes in the gamete. Changes in DNA will be inherited by the germ cells. Germ cells which when passes to the next generation will be inherited in the subsequent generation. Change in the chromosome number makes a change in the gametes which leads to change in the gene pool. This leads to new variations.

9. Differentiate between inherited and acquired traits by giving one example of each. Give reason why the traits acquired during the life time of an individual are not inherited?

Ans.

S. No.	Inherited Traits	Acquired Traits
(1)	Occurs due to a change in genes or DNA.	No change in genes or DNA is involved.
(2)	Pass on from one generation to another. E.g Curly hairs, Brown eyes.	Cannot pass from one generation to another. Eg. Cycling swimming
(3)	These traits are transmitted from parents to their progeny.	These traits or characteristics are not transmitted from one generation to the next.
(4)	Genes of inherited traits are present in the germ cells or DNA.	These traits do not bring about any changes in the germ cells or DNA as these are changes in non-reproductive tissues.
	Example: Shape of ear lobe	Example: Building muscles

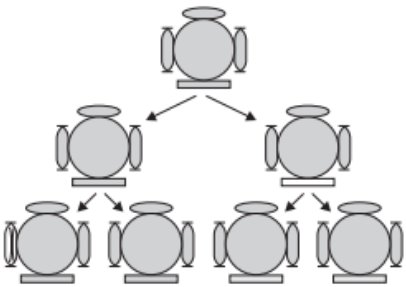
The traits that acquired during the life time of an individual are not inherited because acquired traits do not produce change in the genes of germ cells. These are the traits which occur in the somatic cells. Changes in the somatic cells are not passed on to the offspring belonging to next generation.

Case Based Questions

[4 marks]

10. *Inheritance from the previous generation provides both a common basic body design, and subtle changes in it, for the next generation. The original organism at the top will give rise to two individuals, similar in body design, but with subtle differences. Each of them, in turn, will give rise to two individuals in the next generation. Each of the four individuals in the bottom row will be different from each other.*

While some of these differences will be unique, others will be inherited from their respective parents, who were different from each other. Selection of variants by environmental factors forms the basis for evolutionary processes.



(A) If a trait A exists in 10% of a population of an asexually reproducing species and a trait B exists in 60% of the same population, which trait is likely to have arisen earlier?

(B) How does the creation of variations in a species promote survival?

(C) Which of the processes, sexual reproduction or asexual reproduction, brings about maximum variations in the offsprings?

Ans. (A) Trait B is likely to have arisen earlier because in asexual reproduction traits are carried from parents to offspring with least variations so since trait B has higher percentage it is likely to have arisen earlier.

Related Theory

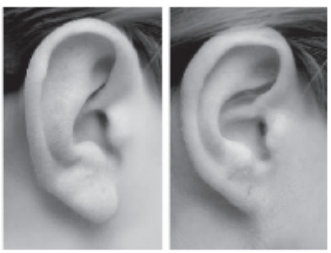
Specialtion is the process by which new species form. It occurs when groups in a species become reproductively isolated and diverge

(B) The variations provide stability to the population of various species by preventing them from getting wiped out during adverse conditions. The natural environment also changes, and variations in species which

become suited to the environment help it to survive.

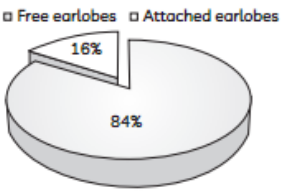
(C) Sexual reproduction brings about maximum variations in the offsprings because the offsprings receive some genes from the mother and some from the father. Due to the maxing of genes of mother and father in various different combinations, all the offsprings have genetic variations. So sexual reproduction brings variety in population.

11. *Observe the ears shown in the image below. The lowest part of the ear, called the earlobe, is closely attached to the side of the head in some of us, and not in others. Free and attached earlobes are two variants found in human populations.*



(a) (b)

The percentage of people having free earlobes and attached earlobes is shown below:



(A) Identify recessive and dominant trait in the given case.

(B) What will be the type of earlobes of a child whose parents have free earlobes?

(C) Mrs. and Mr. Sharma have six children. Three of them have attached earlobes like their father, and the other three have free earlobes like their mother. Taking F for free earlobes and f for attached earlobes. Write the genotype of parents and children.

Ans. (A) Recessive trait : Attached earlobes

Dominant trait: Free earlobes

Explanation: Free earlobes are the most common form of lobes found. This trait is inherited due to the influence of a dominant allele. If the parents' genes get expressed by the dominant allele, then the child will be born with free earlobes. The attached Earlobes are not rare, but are also not commonly found. This kind of lobe's structural formation is due to the absence of the dominant allele in the chromosomes. The recessive allele is expressed instead in the chromosomes to form an attached earlobe.

(B) Parents with free earlobes can have both a copy of the dominant and recessive allele and they may give birth to a child with free or attached earlobes.

(C) All of the individuals with attached earlobes must be ff. All of the individuals with **free earlobes** can be FF or ff. In this particular case, the parent having free earlobe has children who have attached earlobes, so that parent must have a f, and is thus Ff. And all of the children have one parent with attached earlobes, so they must also all have at least one f, and are thus Ff. So the answer is, Mr. Sharma is ff, Mrs. Sharma is Ff. The three children with attached earlobes are ff, and the three with free earlobes are Ff.