Chapter 8

How do Organisms Reproduce?

Introduction

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Heredity

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Variations

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Genetics

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Accumulation of Variations During Reprodcution

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Rules for the Inheritance of Traits- Mendel's Contributions

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Mendel's Experimental Plant :

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S. No.	Characters	Contrasting Traits	
1.	Plant size of height	Tall	Dwarf
2.	Position of flower on the stem	Axial	Terminal
3.	Colour of unripe pod	Green	Yellow
4.	Shape of the pod	Inflated	Constricted
5.	Shape (form) of seed	Round	Wrinkled
6.	Colour of seed	Yellow	Green
7.	Colour of the flower	Violet	White

(iii) All the contrasting traits were existing in every generation because plants had bisexual flowers and normally resorted to self-pollination.

(iv) In this plant, artificial cross fertilization could easily be achieved.

(v) Each pea plant produced many seeds in one generation.

(vi) The garden pea plants could easily be raiseid, maintained and handled.

(vii) The flower structure of Pea is such as two allow controlled breeding. It can be crossbreed manually.

(viii) The plant is grown easily and does not require after case except at the time of pollination.

(ix) Of hybrid plants and raising of subsequent generation like F_2, F_3 and F_4.

Mendel's Experimental Technique

- Mendel conducted breeding experiments in three steps :
  (i) Selection of pure parents (i.e. plants producing similar traits in every generation).
  (ii) Production of first generation of plants by cross-breeding (hybridisation).
  (iii) Raising of second and subsequent generations by self-fertilization of hybrids.
- While performing his cross breeding experiments, Mendel took a number of precautions. he always focussed on the inheritance of the specific traits under consideration and simply ignored others.

Monohybrid cross or Inheritance of One gene

- In cross breeding experiments, Mendel removed the anters (male part) of the flowers well before the maturity of the female part, i.e. gynoecium of the flowers. This process is called **emasculation**. Such flowers were covered to avoid entry of any foreign pollen grain from outside by wind or animals. For making a desired cross, mature pollen grains from the another of the flower of the desired plant were transferred on the stigma 'female part' of the emasculated mature flower. The seeds formed by such crosses were collected. These seeds belonged to the first Filial generation of F_1 generation "A breeding experiment dealing with a single character is called a monohybrid cross".
- Mendel selected 'pure line' plants (i.e. the plants that produced similar traits generation after generation). In one such cross breeding experiment, he cross breed garden pea plant having tall Plant with plant having Dwarf seed.
- In this monohybrid cross, the polln grains from the flower of the desired plant raised from tall plants were transferred over the previously emasclated flower of a plant raised from Dwarf cut or vice-versa.
- After the transfer of pollen grains, the cross-pollinated flower was properly covered and plant produced were allowed to mature. Mendel observed that all the plant of F_1 generation were of U type end there were no intermediate characteristics.
- In a Monohybrid cross, F_2 generation have plants are three tall and oe is Dwarf as phenotypic character.
- **Reciprocal Crosses :** Crosses in which the dominant allele is contributed by one parent and the reserve

allele by the other parent and vice-versa. They give similar results.

- **Back Cross :** It is a cross between F_1 individual and either of the parents (dominant or recessive). I is of two types :

(i) **Out Cross :** A cross between F_1 individual and dominanent parent. When the character is height of the plant. (Tall/Dwarf) and the F_1 outcome is Tt.

Results of outcomes : Tall 100%

(ii) **Test Cross :** A cross between F_1 individual and recessive parent.

Result of Test Cross : Hybrid Tall 50%, pure dwarf 50%.

Mendel's 1st Postulate : Law of Unit Factor

- The observation characters themselves are not inherited but particles, units or factors that determine or control the observable characters (traits) and exist in pairs in an individual organism are transmitted from parents to offspring. Since factors occur in pairs, three combination TT, Tt and tt (homozygous and heterozygous tall and homozygous dwarf).

Mendel's 2nd Postulate : Law of Dominance

- In a cross between two organisms-pure for a particular pair of alternate forms of characters, only one form which is dominant appears in first filial generation and it masks the effect of other, which is recessive.

Mendel's 3rd Postulate : Law of Segregation (Purity of Gametes)

- When a pair of alleles is brought up in a h ybrid, they do not fuse or mix-up rather remain as such and they segregate during anaphase-I. This is also known as the law of purity of gametes since after segregation one gamete inherits only one allele for a character.

Dihybrid Crss

- In order to explain Dihybrid ratio, Mendel considered two characters at a time i.e. colour of the seed and the shape of the seed in another cross in pea plant.

(i) Colour of the Seed – Yellow and Green (YY/yy)

(ii) Shape of the Seed – Round and Wrinkled (RR/rr)

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Mendel's 4th Postulate : Law of Independent Assortment

- When parents showing two or more pairs of constantly characters are crossed the inheritance of any one character is inependent of the inheritance of any other characters.

Mendel's Conclusions : Based on the findings of monohybrid and dihybrid crosses, Mendel concluded that

- **In a Monohybrid Cross :** Only one of two constrasting characters (traits) appeared in F_1 generation. However in F_2 generation, both the parental t raits appeared in certain proportion.

- **In a Dihybrid Cross :** When two constrasting pair of traits were considered simultaneously, only one parental combination appeared in F_1 generation. However in F_2 generation, raised by self pollination, four combinations of traits appeared. There include two parental type traits and two new combinations.

How Do these Traits get Expressed?

- **Mechanism of Heredity :** Deoxyribonucleic acid (DNA) present in the cell is the hereditary material. It is the information source in the cell for making proteins. The specific segment of DNA, having specific sequence of nucleotides, provide information for one protein is called the gene. The gene determine everything about an organism and they control all the characteristics (traits) of the organism. A dominant factor of allele controls the synthesis of a fully functional protein or enzyme to product its morphological or physiological effect. A recessive factor, on the other hand, is able to contribute partially and thus defective, incomplete and less efficient protein or enzyme.
- To explain how do proteins control the characteristics of an organism, let us take the example of Axial position of flower as a characteristic in garden pea plant. The hormones in plants trigger their growth. Thus flower position depends on the amount of a particular hormone synthesised. The amount of the synthesized plant hormone depends on the efficiency of the process for making it. If the specific protein needed for this process is synthesizes and works efficiently, a lot of hormone will be made. The latter will effect more growth and the flower will be at Axial position. If the gene for Axial position is altered, the protein now synthesized is less efficient and therefore the amount of hormone formed will also be less. Consequently, growth of plant will be less and the plant will be dwarf.

Structure of DNA (Deoxyribonucleic Acidd)

- NA was first isolated by the scientist Frederick Meisher from the nucleus of the pus cells, in 1869. He named it as 'nuclein' or nuocleic acid because of its acidic nature. Later, it was ex perimentally proved by the scientist Griffith (1928), and Avery, Mcleod and McCarty (1944) that DNA is the carrier of the genetic information from generation to generation. It transmits the hereditary characters is a coded language from parents to the offspring.
- DNA is macromolecule or polymer. It is made of very large number of 'nucleotide' units and hence is termed polynucleotide.
- Each nucleotide unit in a DNA molecule is made up of three components :

1. **Nitrogenous Base :** Each nucleotide unit has a nitrogen containing base. In a DNA molecule, nitrogenous bases one of two types :
   (a) **Purines :** The purines in a DNA molecule are Adenine (A) and Guanine (G).
   (b) **Pyrimidines :** The pyrimidines in a DNA molecules are cytosine (c) and Thymine (T).
2. **Deoxyribase Sugar :** It is a pentose sugar.
3. **Phosphate Group :** The phosphate group contains one phosphorus atom and four specifically linked oxygen atoms.

- When nitrogen bases are linked with pentose sugar with glycosidic linkage, they are called **Nucleosides** and when nucleoside is linked with phosphate group by phosphodiester bond, are called **Nucleotides.**

Genes

- Mendel was the first scientist to visualise a gene as a unit of inheritance in 1866. He called it 'factor'. The word 'gene' introduced by Johannsen in 1909. The gene was considered the u nit of inheritance and it is made up of segments of DNA on a chromosome occupying specific positions. For example 30,000 – 40,000 genes are present on 46 human chromosomes.

- On the basis of modern molecular concept, a gene is a hereditary unit, a segment of DNA having specific sequence of nucleotides that determines its specific b iological function. It can maintain constancy from generation to generation but at times may also undergo sudden mutations (inheritable changes) to bring variations.

Sex Determination

- The sexual re production, male and female gametes fuse during fertilisation to form zygote. This zygotes then dvelops into the offspring (male or female). “The mechanism by which the sex of an individual is determined as it begins life, is called sex determination”.
- Human beings have 22 pairs of autosomes and one pair of sex chromosomes. All the ova formed female are similar in their chromosomal type (22 + X). Therefore females are homogametic. The male gametes of sperms produced by human males are of two t yopes, (22 + x) and (22 + y). Human males are therefore heterogametic (male diagamety).
- Sex of the offspring is determined at the time of fertilisation. It cannot be changed later on. It is also not dependent on any characteristic of the female parent because the latter is homogametic and produces only one type of eggs (22 + x). The male gametes are of two types, androsperms (22 + y) and gymnosperms (22 + x). They are produced is equal proportion. Fertilization of the egg (22 + x) with a gymnosperm (22 + x) will produce a female child (44 + xx) which fertilization with an androsperm (22 + 4) gives rise to male child (44 + xy). There qre equal chances of getting a male or female child in a particular mating. As Y-chromosome determines the male sex of the individual, it is also called androsome.

Evoluton

- The branch of biology that deals with the changes and its causes in the diversity of living organisms over the period of time is called evolution.
- The concept of organic evolution was first given by Charles Darwin which simply means ‘descent with modification’. The organic evolution states that “the present day complex organisms have originated from the earlier simpler forms of life during the course of ages by the process of gradual change”.

Example

(i) Imagine that a group of 12 red and beeles live on green leaves of some bushes.

(ii) These beetles have the natural tendency to increase in numbers by sexual reproduction and consequently generate variations.

(iii) Let consider that crows are the natural predators of these beetles. The crow regulate the population of beetles by eating them and therefore fever beetles are available for sexual reproductioin.

(iv) **In one situation :** Let us assume that **beetles develop colour variation** during reproduction. Consequently, in the progeny, one beetle develops green body colour instead of normal red colour. This beetle can inherit this variation in colour on to its progeny so that all its offspring are green in colour. Crows cannot locate green-coloured beetles on the green leaves of bushes but continue to eat red beetles which are easily located on green leaves by them. As a result, number of green beetles in beetle population increases in each generation.

(v) Let us consider a **second situation**, Another colour variation arises in beetles during sexual reproduction and in the progeny, one beetle develops blue body colour instead of normal red. This beetle can also pass this colour variation to its progeny so that all its offsprings are blue coloured beetles. Crows can detect

both **red and blue** coloured beetles easily on green leaves of bushes and eat them regularly. As the population of beetles expands, initially there are few blue coloured beetles among the majority of red coloured beetles. At this point on elephant comes by and stamps on the brushes where the beetles live. Consequently, most of the beetles are now blue coloured. This population again slowly expands and will contain mostly blue coloured beetles over a period of time.

(vi) Let us consider a **third situation**. As the beetle population starts expanding by sexual reproduction, a plant disease spreads resulting in decrease in the amount of leaf material in the bushes. Expanding population of beetles is now poorly nourished. Consequently the average weight of adult beetles decrease compared to what it used to be when leaves in the bushes were in plenty. After a few years time and a few beetle generations of such scarcity, the plant disease is eliminated. Now, more leaves of bushes are available as food for the beetles.

Decrease in the body weight due to starvation is an acquired trait in the beetles during their life time. It will not bring any change in the DNA and therefore, this trait cannot be inherited. When food becomes abundant after few generations, the beetles could gain weight.

Inherited and Acquired Traits :

Inherited Traits : These traits are controlled by specific genes the DNA (genes) will be passed on, through gene cells, to the progeny resulting in variation in them.

Acquired Traits : Certain traits are acquired by organisms in their life time. For instance decrease in the body weight of beetles due to starvation is an acquired trait by the beetles during their life time. It involves changes in the non-reproductive tissues caused by environmental factors. It will not being any change in the DNA.

Speciation

"Origin of new species from the existing one, due to reproductive isolation of a part of its population is called speciation".

Microevolution

It means that the changes are small, even though they are significant. The causes of microevolution include **gene mutation** and **gene recombination.**

Examples of microevolution include pesticide resistance, high temperature, tolerance etc.

Microevolution does not properly explain how new species arise from the eixisting ones.

Macroevolution : – It involves origin of new species, **genera** and **higher taxa**.

Mechanism of Speciation

To explain the mechanism of speciation, lets us cosndier a situation that the bushes on whcih the beetles live are widely spread over a mountaion range and over a period of time beetle population becomes ve ry large.

In the large beetle population, individual beetles normally do not travel far. Instead, they continue to feed in new nearly bushes only thoughout their life time.

Most of the male and female beetles reproduce sexually only within the respective terms (sub-populations).

Rarely an adventurous beetle might go from one sub-population to another or alternatively it is picked up

by predator crow from one site and dropped in the other site without being eaten. In either case, the migraint beetle gets in opportunity to reproduce with local inhabitant of this suob-population.

As a result, genes of migrant beetle enter into the gene pool of this sub-population. Such kind of gene flow, happens between sub-poplations that are only partly separated.

After few generations, **genetic drift** will accumulate different variations in each of the two geographically separated sub-poplulations. Natural selection may also operate simultaneously in a different way in these geographically isolated **sub-populations**.

For instance, in one geographical region, cois are systematically killed by eagles whereas in the other geographical region no such changes occurs and numbers of cows is very high.

Consequently, green body colour variation will not be selected at the first geographical region while it will be strongly selected at the other geographical site.

In this way, both genetic drift and natural selection make these geographically isolated sub-populations to become more and more different from each other.

Ultimately, reproductive isolation occurs between individuals of these two groups. As a result, they are unable to reproduce even if they happen to meet somehow. These two groups then transform into new species.

Evolution and Classification

Classification refers to the arrangement of organisms into groups, sub-groups on the basis of similarities/ dissimilarities and placing them in a ierarchy that reveals their relationship.

Characteristics of organisms refers that distinguish then from one another. They include **ancestral** (basic) and **derived** characteristics.

Incestral or Basic Characteristics

Are present in all members of a population and thus, form their basic body design.

Derived Characteristics :

Develop due to evolutionary changes in ancestral (basic) characteristics.

These are some basic characteristic that are shared by most organisms. For instannce, body of all the animals and plants is formed of microscopic units and **cells**.

Organisms can be classificed into two broad groups i.e. eukaryotes and prokaryotes on the basis whether their cells possess well defined nucleus and other organelles or not.

(i) Similarly, eukarytoes can be grouped into unicellular and multicellular organisms on the basis of whether they are made of single cell or large number of cells.

(ii) Organisms even can be classifieed into plants and animals on the basis of photosythetic property.

(iii) Multicellular organisms can further be grouped on the basis of levels of body organization. For instance,

(i) **Sponges :** Cell function more or less independently without porifera or organizing themselves into tissues, so sponges have cellular level of organization.

(ii) **In coelenterates :** the cells are aggregated into tissues but the tissues do not form organs. This produces tissue levels of organization.

(iii) **Platyhelminthes (flatworms) to chordates :** All animals have organ system level of organization. This gradual change from simple to complex organization is evolution.

Tracing Evolutionary Relationoships

- Enormous types of organisms that exist on the earth at present and also the fossils have large number of common feaures which provide evidences in favour of organic evolution and help us in tracing evolutionary relationships. All these evidences support the view that the present day diverse forms of living organisms have evolved from common ancestors. These evidences have been cat egorized under the following heads :

(i) **Morphological and Anatomical Evidences**

These evidences are based on the similarities in the external and internal feaures of the different kinds of organisms. These features are :

(a) **Homologus Organs :** The organs which perform different functions in different species but have similar basic structure and similar embryonic origin are called homologous organs.

For example : The forelimbs of a frog, a lizard, a bird and a human being show similarity in basic structure. However, these organs perform entirely different functions : the forelimbs of a frog help the animal to prop up the front end of the body at rest, and also acts as shock absorbs when the animal lands on the ground after a leap (jump). The forelimbs of a lizard are modified for a creeping movements; the forelimbs of a bird are modified fo flying purposes, while the forelimbs of a human being are used for grasping.

The basic similarity in the forelimbs of these different vertebrates indicates that all these vertebrates had common ancestors i.e. they have evolved from a common ancestor who had ‘five digited’ or ‘pentadactyle’ limbs. The pentadactyle limbs of the ancestral veretebrate became modified according to the special needs of the subsequent generations during the course of evolution. The modificaion in the limbs in these vertebrate include :

(i) Reduction in number of digits

(ii) Fusion of certain bones

(iii) External form

Plants also have homologous organs. For example, a thorn of Bougainvillea plant and a tendril of passiflora plant are homologous organs. Both these perform different functions but have similar basic structural design i.e. both are modified branches.

Analogous Organs

The organs which are quite different in fundamental structure and embryonic origin but perform same function and may superficially look alike in entirely different species are called analogous organs.

The wings of an insect and a bird are analogous organs. It is so because both these organs in entirely different animals perform similar functions i.e. they are used for fl ying in the air. However they are very different in structure. An insect wing is a fold of membrane which is supported with few muscles.

On the other hand, wings of a bird are formed of limb bones covered with flash, skin and feathers.

The superficial similarity of these organs is due to adaptation to flying rather than to inheritance from a common ancestor.

The insects and birds, in fact, have evolved from separate ancestral populations, but perform similar functions. i.e. flying as a means of more efficient mode of locomotion.

Similarly, the wing of a bat (mammal) and the wing of a bird are analogous organs. A close examination of these structures will reveal that wings of bats are skin folds. Stretched mainly b etween elongated fingers. However, the wings of a bird are feathery covering all along the arm. The basic designs of the wings of bat and the bird, their structures and components are very different. They only look similar because both are adapted for flying but their origin are not common.

	Homologous Organs		**Analogous Organs**
1.	These generally look similar externally	1.	These generally look different externally
2.	These generally perform different functions	2.	These perform similar function
3.	These are similar in basic plan and origin	3.	They are different in basic plan and origin.
4.	These depict divergent evolution or adaptive radiations	4.	They show convergent evolution.

Palaeontological Evidences (G. Palaios = old, ancient, ontos = being; logos = study)

Fossils : Normally, when the organisms, die their bodies are decomposed and lost. However, if the body or some of its parts remain in an environment/medium that does not let it decompose completely, the body or its parts will eventually be preserved or alternately leave the impressions.

Thus,

“Fossil are the remains or impressions of the dead animals and plants that lived in the remote past”.

How do Fossils form layer by layer?

Some 100 million years ago, for instance, some invertebrates died on the sea bed and got burried in the soil/sand. Mone soil/sand was carried by rain into the streams and rivers and ultimately into the oceans, where it settled at the bottom layer after layer.

In the course of time, the layers so deposited changed into rocks (sand stone) due to the presence of the water above and also due to chemical reactions.

Millions of years laters dinosaurs living in the area died and their bodies to got buried in mud. The mud also got compressed into rock in the course of time over the rock containing the earlier invertebrates fossils.

Again millions of years later, bodies of horse like creatures died in the area and got fossilised in rocks above the earlier formed rocks. The rocks formed in this manner at the ocean floor are known as sedimentary rocks. Millions of year later, say erosion by water flow e xposed the horse-like fossils. If we dig deeper, we sould come across older and older fosslis.

Various kinds of fossils have been unearthed from sedimentary rocks. These include many fossil invertebrates (e.g. *Ammonites*, *Trilobites*), *fossil fish* (*knigtia*), dinosaur’s shal of **Rajasaurus** (from **Narmada valley**). The fossils provide direct evidence of evolution.

How do we know the age of fossils?

There are two ways to know the age of fossils :

1. **First way is relative :** If we dig the earth to locate fossils the fossils we find closer to the surface are more recent than the fossils we find in deeper layers.
2. **Second way in to date the rocks or fossils :** Dating the rocks or fossils is done by working out the ratio of uranium to lead in a rock or fossil.

   Radioactive potassium and Argon dating is also used where the age of fossils is several millions of oyears. Similarly, carbo (^{14}C) dating is also done for calculating the age of recent fossils.

   Example : The fossil bird, Archaeopteryx lived in the Jurassic period abotu 180 million years ago. It had feathers which are exclusively bird structures. It also had fused bones, beak and some other bird characters. But, it also had number of Which are found in reptiles e.g. teeth in the jaws, claws on free figures, a long tail etc. Thus, Archaeopterx represents a stage midway between the reptiles and birds, and is often called the lizard bird. This example provides a clue that the birds have evolved from reptiles.

Human Evolution

Human beings and great apes (e.g. gorilla, chimpanzee) are closely related species. There had a common ancestor a long time ago.

In human beings, these occurs a great diversity in form and features across the globe.

For a long time, we used to cosider these human forms as ‘human races’.

Our this belief was based on skin colour and other morphological features and accordingly we designated then as yellow, black, white or brown skin coloured forms.

For a considerable period of time, biologists debated on the possibility of evolution of these apparent ‘human forms’ in different ways.

However, on the basis of time dating, study of fossils and molecular playogeny involving DNA sequences, it is clear that all humans belong to a single species, “Homo sapiens”.

The earliest members of Homo sapiens have been traced book of Africa. Some of our ancestors stayed back in Africa and spread across this continent; others left Africa and slowly spread across the planet over a period of time.

They moved forward and backward in groups, revealing separation or mixing of groups at times.

These groups of ancestors, like other species, lived their lives in then prevailing environment and developed genetic variations to become different coloured with specific features in different geographical regions in modern times.

Difference between artificial selection and natural selection

	Artificial Selection		Natural Selection
1.	It is an artificial process	1.	It is a natural phenomenon
2.	It is controlled by man on a limited scale in specific laboratories	2.	It is conducted by nature on a vast scale all over the world
3.	Traits selected for improvement are beneficial to man	3.	Traits selected for evolution are beneficial to the species
4.	Results are achieved in a short period e.g. cows with high milk yield	4.	Results are achieved over a long period of time.

EXERCISES

Answer the following in very briefly:

1. What are lichens?
2. Name the bacteria which can convert atmospheric N_2 into soluble form.
3. Define nutrition.
4. What is photosynthesis?
5. Name the pore through which leaves exchange gases.
6. How does water reach the leaves for synthesising food?