Key learning:

1) Variations arise during the process of reproduction. They may be few in asexual reproduction, but many in case of sexual reproduction.

2) The minor variations arising during asexual reproduction are caused by slight inaccuracies in DNA copying. In sexual reproduction, variations are also caused by crossing over process of meiosis.

3) Beneficial variations help the species to survive better in the environment.

4) Nature selects the beneficial variations thereby leading to evolution.

5) Reproduction produces offsprings with similar body design of the parents. However the offspring are not identical, but show a great deal of variation from the parents.

6) Sexually reproducing organisms like humans have 2 (or more) versions of genes for each trait, called alleles.

7) Gregor Johann Mendel carried out several experiments on pea plants. He carried out large number of monohybrid and dihybrid crosses using many contrasting characteristics and put forward several important conclusions.

8) In case of monohybrid cross with pure variety of plants, the phenotypic ratio obtained in $F_2$ generation is 3:1.

9) In case of dihybrid cross involving 2 pairs of contrasting characters, the phenotypic ratio obtained in $F_2$ generation is 9:3:3:1.

10) Mendel concluded that out of any pair of contrasting characters, one is dominant and the other recessive.

11) The homozygous dominant trait is denoted by two capital letters whereas the homozygous recessive trait is denoted by two small letters.
12) The factors or genes controlling a particular trait separate from each other during gamete formation. Hence gamete is always pure as far as contrasting characters are considered. Each gamete will possess only one gene set.

13) In crossing if two or more traits are involved, their genes assort independently, irrespective of the combinations present in the parents.

14) Genes carry information for producing proteins, which in turn control the various body characteristics.

15) For a particular trait, the offspring receives one allele from the father and one allele from the mother.

16) The combination of the male and female germ cells gives a diploid zygote. Thus the normal diploid number of chromosomes in the offspring is restored.

17) Different mechanisms are used for sex determination in different species.

18) The sex of human offspring is genetically determined.

19) Humans have 22 pairs of autosomes and one pair of sex chromosomes.

20) Females have similar sex chromosomes XX, whereas males have an imperfect pair i.e. XY. All eggs carry X chromosome.

21) The sex of the child depends on whether the egg fuses with the sperm carrying X chromosome (resulting in a girl) or with the sperm carrying Y chromosome (resulting in a boy).

22) Variations beneficial to a species have a greater chance of flourishing in the species than the harmful or neutral variations.

23) Genetic drift can alter gene frequencies in small population and provide diversity without any survival benefits.

24) Several factors like environment, mutations, reproduction etc can cause alterations in gene frequencies in a population over generations, leading to evolution.

25) Changes occurring in the DNA of germ cells are heritable whereas changes taking place in the non-reproductive tissues are not inherited.

26) Charles Darwin proposed that evolution of species occurred by natural selection, but he did not know the underlying mechanism.
27) Natural selection, genetic drift, variations and geographical isolation can lead to speciation in sexually reproducing organisms.

28) Gene flow between the members of a population prevents speciation.

29) The fundamental characteristics used to classify organisms are:
   - presence of prokaryotic or eukaryotic cells
   - whether the organism is unicellular or multicellular
   - ability to perform photosynthesis
   - presence of endoskeleton or exoskeleton in heterotrophic organisms.

30) Classification of living organisms is closely related to their evolution.

31) As we go back in time to trace common ancestors, we find that all organisms must have arisen and radiated from a single species, which in turn originated from non-living material. Thus life arose from non-living matter.

32) Study of homologous organs, e.g. hand of man and wing of bird, helps in tracing the evolutionary relationship between different species.

33) Analogous organs, e.g. wing of insect and wing of bird, do not have common origins, but arose in different species to fulfill similar functions.

34) Fossils help in tracing evolutionary pathways.

35) The age of fossils can be determined by using the relative method or the isotope dating method.

36) Evolution is not a one-step process, but a continuous process occurring in several stages.

37) Complex organs are formed slowly over many generations, sometimes with intermediate forms playing an important role.

38) Sometimes the use of certain features gets modified with time. For example- Feathers may have provided insulation initially, but later became associated with flight.

39) Evolutionary studies have shown that birds are closely related to reptiles.

40) Humans have carried out artificial selection for various features of cabbage and produced different vegetables.

<table>
<thead>
<tr>
<th>Vegetable produced</th>
<th>Selected feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli</td>
<td>Arrested flower development</td>
</tr>
</tbody>
</table>
41) Molecular phylogeny can also be used to trace evolutionary relationships. Here the DNA of different species is compared. Greater the differences in DNA, more distantly related are the species.

42) Disappearance of the existing species is not a requirement for formation of new species.

43) The new species formed are better adapted to the environment, but they need not be superior to the existing species.

44) The common ancestor of humans and chimpanzees evolved in different ways to produce the present forms.

45) Evolution produces more diverse and complex body forms over time, but the newly formed species are not more progressive than the already existing ones. So it is wrong to say that evolution produces progressive higher forms from lower ones.

46) All human beings, whether fair skinned or dark skinned, belong to the same species i.e. *Homo sapiens* that originated in Africa.

47) The human ancestors gradually migrated from Africa to various parts of the world like Asia, Europe, Australia and America. Thus they spread to different parts of the Earth and adapted as best as they could to their environmental conditions.

**Top Definitions**

1) F₁ generation- The generation resulting immediately from a cross of the first set of parents (parental generation).

2) F₂ generation – Offspring resulting from a cross of the members of F1 generation.

3) Progeny - The offspring produced as a result of reproduction of the parents.
4) Dominant trait - A genetic trait is considered dominant if it is expressed in a person who has only one copy of that gene.

5) Recessive trait – A genetic trait that is expressed only when two copies of the gene are present.

6) Homozygous - having two identical alleles of the same gene

7) Heterozygous - having dissimilar alleles at corresponding chromosomal loci

8) Monohybrid cross – A type of crossing in which only one pair of contrasting characters are considered.

9) Dihybrid cross – A type of cross that involves two sets of characteristics.

10) Allele – Either of a pair (or series) of alternative forms of a gene that can occupy the same locus on a particular chromosome and that control the same character.

11) Somatic cells- All cells forming the body of an organism, except the reproductive cells.

12) Sex chromosomes – Either of a pair of chromosomes, usually designated X or Y, in the germ cells of most animals, that combine to determine the sex and sex-linked characteristics of an individual.

13) Gene – A segment of DNA that is involved in producing a polypeptide chain and forms the basic unit of heredity.

14) Trait – A trait is a distinct variant of a phenotypic character of an organism that may be inherited or environmentally determined.

15) Haploid cell – Cell having only one complete set of chromosomes

16) Diploid cell – Cell having two sets of chromosomes, one of paternal origin, the other maternal.

17) Micro-evolution – Evolution resulting from small specific genetic changes that can lead to a new subspecies.
18) Genetic drift - It refers to the random change in gene frequencies in a small population, presumably owing to chance rather than natural selection, thereby providing diversity without any adaptations.

19) Speciation - The process of formation of a new species.

20) Homologous organs – Organs of different organisms which may be dissimilar externally, but are similar in origin and in fundamental structural plan.

21) Analogous organs – Organs of different organisms which are similar in function and external appearance, but dissimilar in origin and structural plan.

22) Fossils – All preserved traces of living organisms.

23) Molecular phylogeny - The use of a gene's molecular characteristics to trace the evolutionary history of organisms.
Top diagrams / charts

Creation of diversity over succeeding generations

<table>
<thead>
<tr>
<th>Pure tall pea plant</th>
<th>x</th>
<th>Pure dwarf pea plant</th>
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</thead>
<tbody>
<tr>
<td>TT</td>
<td></td>
<td>tt .......................... Parents</td>
</tr>
<tr>
<td>↓</td>
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<tr>
<td>T</td>
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<td>t  ............................ Gametes</td>
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<tr>
<td>Tt</td>
<td></td>
<td>............................... F₁</td>
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<td>(Hybrid tall)</td>
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Tt  x  Tt  ........................................... Selfing.

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<tbody>
<tr>
<td>TT (Pure tall)</td>
<td>Tt (Hybrid tall)</td>
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<tr>
<td>t</td>
<td>tt( Pure dwarf)</td>
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</tbody>
</table>

................................................................. F₂

So the ratio of plants in F₂ generation is 3(tall) : 1(short)

Inheritance of a trait (e.g. height) over two generations
Plant with round green seeds $\text{RR}yy \times \text{rrYY}$ Parents

$\text{Ry} \times \text{rY}$ Gametes

$\text{RrYy}$ (Round yellow) $\text{F}_1$

(The gametes obtained by selfing the plants of $\text{F}_1$ are: $\text{RY}$, $\text{Ry}$, $\text{rY}$, $\text{ry}$)

On selfing the $\text{F}_1$ plants,

<table>
<thead>
<tr>
<th>Male $\rightarrow$ Female $\downarrow$</th>
<th>$\text{RY}$</th>
<th>$\text{Ry}$</th>
<th>$\text{rY}$</th>
<th>$\text{ry}$</th>
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<tbody>
<tr>
<td>$\text{RY}$</td>
<td>$\text{RRYY}$ (Round yellow seeds)</td>
<td>$\text{RRYy}$ (Round yellow seeds)</td>
<td>$\text{RrYY}$ (Round yellow seeds)</td>
<td>$\text{RrYy}$ (Round yellow seeds)</td>
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<tr>
<td>$\text{Ry}$</td>
<td>$\text{RRYy}$ (Round yellow seeds)</td>
<td>$\text{RRyy}$ (Round green seeds)</td>
<td>$\text{RrYy}$ (Round yellow seeds)</td>
<td>$\text{RrYy}$ (Round green seeds)</td>
</tr>
<tr>
<td>$\text{rY}$</td>
<td>$\text{RrYY}$ (Round yellow seeds)</td>
<td>$\text{RrYy}$ (Round yellow seeds)</td>
<td>$\text{rrYY}$ (Wrinkled yellow seeds)</td>
<td>$\text{rrYy}$ (Wrinkled yellow seeds)</td>
</tr>
<tr>
<td>$\text{ry}$</td>
<td>$\text{RrYy}$ (Round yellow seeds)</td>
<td>$\text{Rryy}$ (Round green seeds)</td>
<td>$\text{rrYy}$ (Wrinkled yellow seeds)</td>
<td>$\text{rryy}$ (Wrinkled green seeds)</td>
</tr>
</tbody>
</table>

$\text{F}_2$

So the ratio of plants in $\text{F}_2$ generation is $9$ (Round yellow seeds) : $3$ (Round green seeds) : $3$ (Wrinkled yellow seeds) : $1$ (Wrinkled green seeds)

**Independent inheritance of two separate traits, shape and colour of seeds**
Sex determination in humans

Gametes

XY
Male

XX
Female

Zygote

XX
Female

XY
Male

Offsprings
Homologous organs

Analogous organs (Wing of bat and wing of bird)

Fossil - invertebrate (Ammonite)
Fossil – invertebrate (Trilobite)

Fossil – dinosaur skull (Rajasaurus)

Eye-spots of Planaria
Evolution of wild cabbage

Evolution – Ladder versus tree