HEREDITY AND EVOLUTION

HEREDITY AND VARIATION

A cow gives birth to a calf, a cat to a kitten and so forth. However, on close observation of a cow and its calf or a cat and its kitten, we see a number of differences such as the colour of the skin, size etc. So the conclusion to be derived is that, the offspring, by virtue of being the progeny, need not be an exact replica of its parents.

Inheritable characteristics of the parents are passed on from one generation to the next through genes. No two individuals, even biologically related individuals, are alike in every way and the differences in their characteristics are defined as variation. Living organisms show a great deal of variation.

HEREDITY

The rules of heredity determine the process by which the traits and the characteristics are relatively inherited.

"The inheritance of characteristics from one generation to another generation is called heredity."

The inheritable characteristics (traits) may be morphological / anatomical / physiological / reproductive.

If we take a very close look at the rules of inheritance, both father and mother contribute an equal amount of genetic material to the child. This means that each trait can be influenced by both paternal and maternal genetic material – i.e. DNA.

Gregor Johann Mendel (1822- 1884) conducted the first ever scientific experimental study on heredity. Mendel, an Austrian Augustinian monk, observed variations in the characteristics of garden pea plant (*Pisum sativum*) which, he had cultivated in his monastery garden. Mendel was curious to find out the results of crossing of pea plants with variation in traits.

The visible contrasting characteristics that Mendel focussed on the garden pea plants were:

- Seed shape - Round / Wrinkled
- Seed colour - Yellow / Green
- Flower colour - Violet / White
- Pod shape - Full / Constricted
- Pod colour - Green / Yellow
- Flower position - Axillary / Terminal
- Stem height - Tall / Dwarf

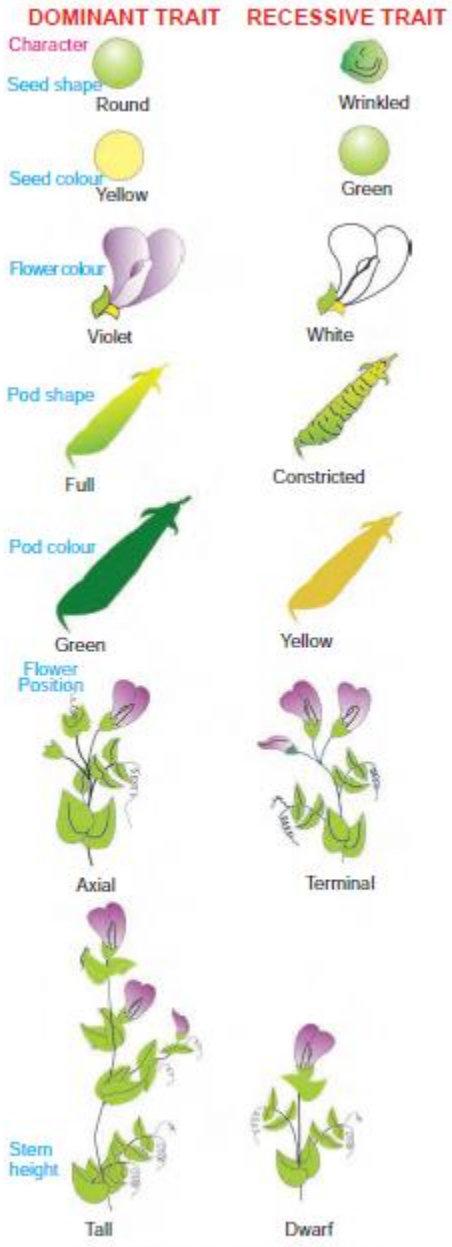


Fig. 1.1 Seven pairs of contrasting traits in Pea plant studied by Mendel.

1.1.1. Mendel's Monohybrid Cross

Mendel selected tall and dwarf garden pea plants, *Pisum sativum*, for his experiments. Mendel selected tall and dwarf pea plants for his experiments. He observed their growth for nearly two years and found that tall plants always produce tall plants and dwarf plants produce dwarf plants - generation after generation, on self pollination and under natural conditions. He termed those tall and dwarf plants as "wild types" or "pure breeding" varieties.

He crossed a tall plant with a dwarf plant, and observed how the traits are transmitted the progeny and calculated the percentage of tallness and dwarfness in subsequent generations.

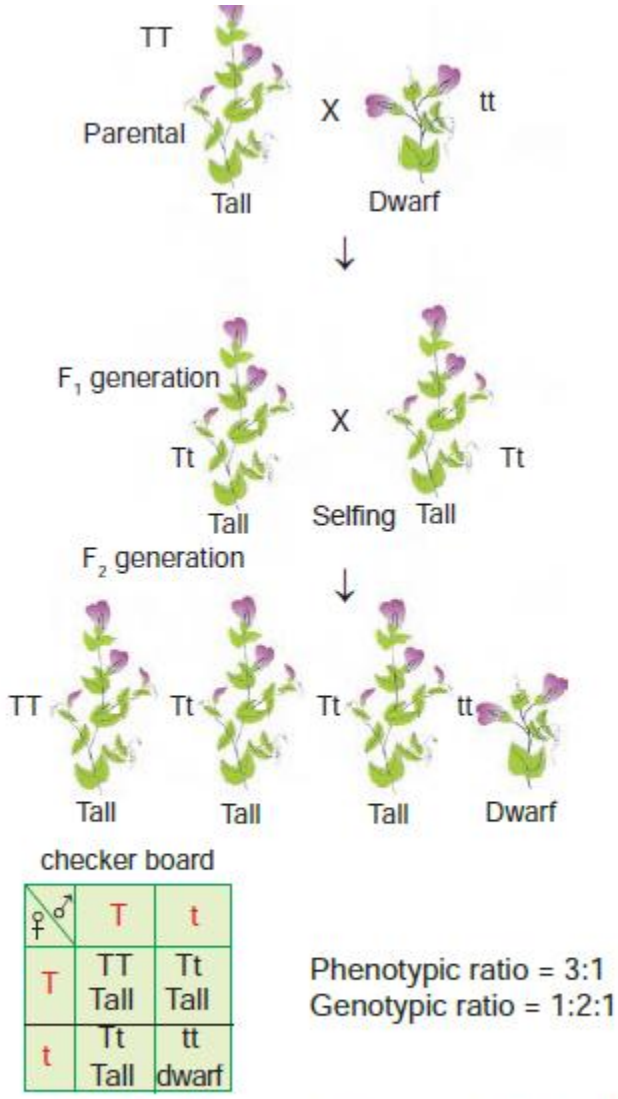


Fig. 1.2 Diagrammatic representation of Monohybrid cross

When a pure breeding tall plant (TT) was crossed with a pure breeding dwarf plant(tt), all plants were tall in the first filial generation(F1) i.e. there was not any medium height plants or dwarf plants.This means that only one of the parental

Gregor Johann Mendel (1822-1884)

Mendel was educated in a monastery and went on to study science and mathematics at the university of Vienna. Failure in the examinations for a teaching certificate did not suppress his zeal for scientific quest. He went back to his monastery and set out experimenting on pea plants. Many others had studied the inheritance of traits in peas and other organisms earlier, but Mendel blended his knowledge of Science and Mathematics and was the first one to keep count of individuals exhibiting a particular trait in each generation. This helped him to arrive at the laws of inheritance that we have discussed in the main text.

traits was seen and not a mixture of the two. When such an F1 tall plant(Tt) was allowed to self-pollination, both the tall and dwarf plants appeared in second filial generation (F2) in the ratio of 3:1. This indicates that both tallness and dwarfness were inherited in the F1 plants but only one trait was expressed, i.e. tallness. The trait which is expressed is called dominant. The hidden trait is called the recessive trait.

The first experiment of Mendel considering the inheritance of a single trait (Height of the plant-Tall/Dwarf) is called Monohybrid Cross.

Expression of morphological characters (as tall or dwarf plant, violet or white flower) is called Phenotype. Genetic make up of an individual for a particular trait is called Genotype. The genotype of a character is influenced by certain factors.

PHYSICAL BASIS OF HEREDITY

The unit of inheritance or the determinant of a trait(character) is called gene.The genes are the factors which form the physical basis for inheritance of Characters. The alternate forms of the same gene are called alleles. The expression of contrasting pair of alleles(Tt) makes up an allelomorph. Examples : Height of plant (Tt), shape of seed (Rr). Recombination in expressing phenotype leads to variation.

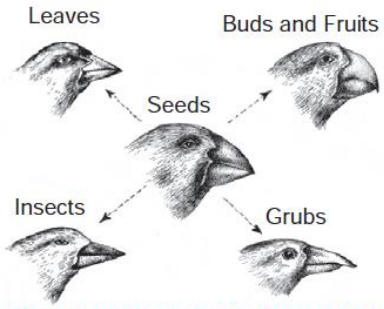


Fig. 1.3 Variations in the beaks of finches to suit their eating habits.

VARIATION

All around us, we see different organisms belonging to different species, differing from one another. Variation may be defined as differences in the characteristics among the individuals of the same species, (A) Intra specific variation or among the different genera (B) Intergeneric variation or among different species (C) Inter specific variation. No two individuals are identical. Asexual reproduction produces very closely resembling offspring. Asexual reproduction thus results in offspring with minor variations. Sexually reproducing organisms produce offspring with marked, significant and visible variations.

Types of Variations

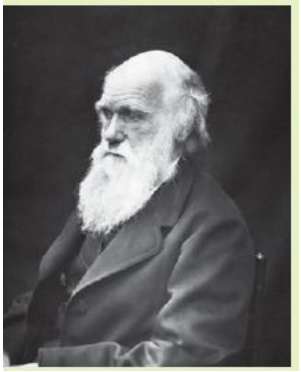
a. *Somatic Variation* - It pertains to body cells and it is not inherited.
b. Germinal Variation - It pertains to germ cells or gametes and it is inheritable. It leads to speciation and evolution.

Significance of Variation

- It is the source of raw material for evolution.
- Animals are able to adapt themselves to the changing environment.
- Organisms are better suited to face the struggle for existence.
- Variations give the organisms an individuality of their own.

- Without variations there would be no science of evolution, as all individuals of a race would be identical in all aspects.

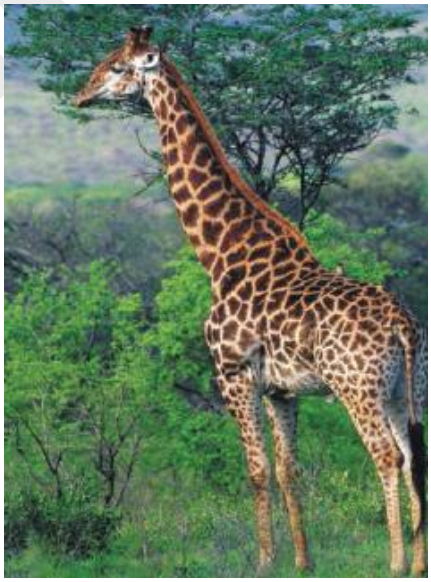
Charles Darwin: (1809-1882)



Charles Darwin set out on a voyage, when he was 22 years old. The 5 yearvoyage took him to South America and the islands off its coast. Interestingly, after he got back to England, he never left the shores again. He stayed at home and conducted various experiments that led him to formulate his theory of evolution. He did not know the mechanism by which the variations arose in the species. Had he been enlightened by Mendel's experiments, he would have contributed more. These two great men did not know of each other or of their works.

We often associate Darwin solely with the theory of evolution, but he was an accomplished naturalist, and one of the studies he conducted with the role of earthworms in soil fertility.

Lamarckian View on Organic Evolution



Jean Baptiste Lamarck (1744-1829) postulated the Use and Disuse Theory. According to Lamarck, the use of a part / an organ efficiently by a species, for generations over a long period of time, results in that part / organ being well developed in the subsequent generations and disuse of part / organ for a long period would make that part / organ to diminish or degenerate.

Lamarck quotes the example of the development of the long neck of the giraffe. Giraffes were forced to extend their neck and stretch their legs to reach the leaves of tall trees. Over a long period of time, this resulted in long neck and long legs in giraffes. Lamarck remarks that the "will or want" for a character makes the organisms to possess it at a later time.

THEORY OF NATURAL SELECTION

Charles Darwin made a number of observations in many parts of the world and put forth the law of natural selection involving struggle for existence and survival of the fittest.

Variation leads to genetic diversity,which is the staircase of evolution.

Evolution

Evolution may be defined as a gradual development of more complex species from pre-existing simpler forms.

It is an extremely slow process and has been occuring since millions of years, as revealed by fossil evidence.

Evolution has thus resulted in the diversity of organisms, influenced by environmental selection.

Human Evolution

Fifteen million years ago, the hairy bodied gorilla and chimpanzees like Hominids existed in Africa. 3-4 million years ago, men like hominids walked into Eastern Africa. Evidence shows that they hunted with stone weapons but were mostly fruit eaters. They were probably not taller than four feet, but walked upright in the grass lands of East Africa. These creatures were called the first human-like beings – the Hominid. The Hominid was called *Homo habilis.*

The next stage of human evolution came into existence 1.5 million years ago with the rise of *Homo erectus* who were meat eaters.

The Neanderthal man who lived in East and Central Asia 1 million years ago, used to hide to protect themselves and buried their dead.

Archaic *Homo sapiens* arose in South Africa and moved across continents and developed into distinct races during the ice age. It is believed that homosapiens came into existence about 75,000 to 10,000 years ago. Pre-historic caves were developed about 18,000 years ago, agriculture came around 10,000 years back and human settlements started.

The Tree of Evolution

To understand evolution, a branching diagram (a tree diagram) is used to illustrate the inferred evolution, relationships, among

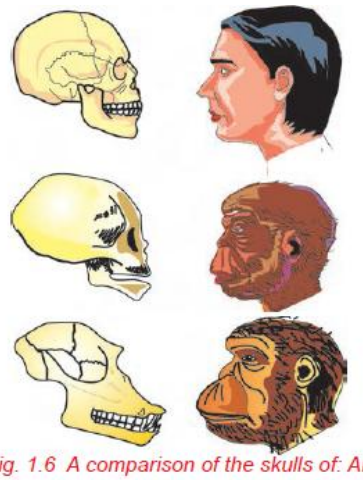


Fig. 1.6 A comparison of the skulls of: An adult modern human being, baby chimpanzee and adult chimpanzee. The skull of the baby chimpanzee is more like the adult human skull than the adult chimpanzee skull.

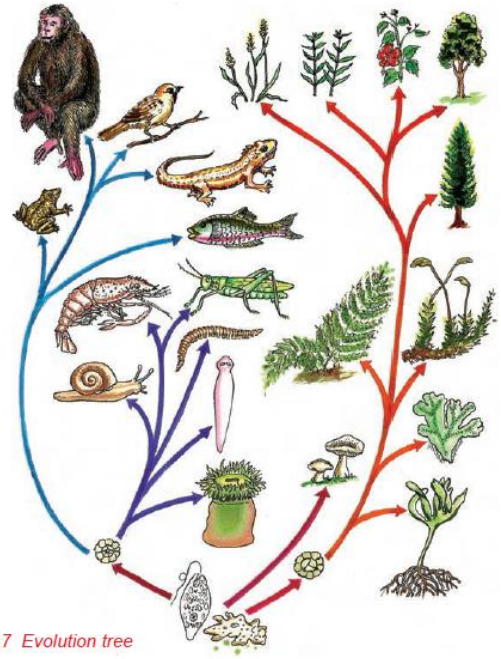


Fig. 1.7 Evolution tree

various biological species or other entities based upon similarities and differences in their physical and genetic characters.

GENETIC ENGINEERING

Genetic engineering is the modification of the genetic information of living organisms by manipulation of DNA i.e. by adding, removing or repairing part of genetic material (DNA) and changing the phenotype of the organism.

It is also known as gene manipulation or Recombinant DNA Technology (r-DNA Technology)

Recent advances made in Genetics, Molecular Biology and Biochemistry have resulted in the origin of this new branch of science.

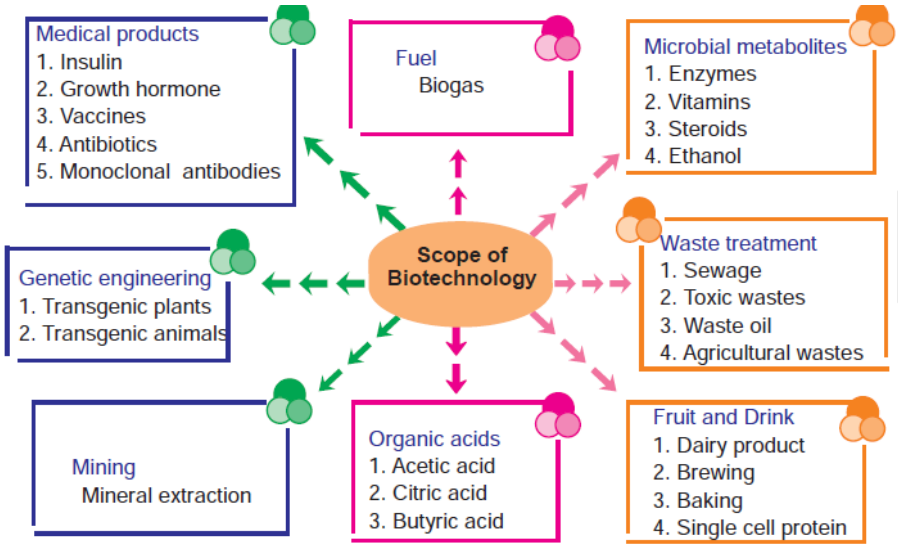
Merits of Genetic Engineering

- Understanding of the gene structure and function through basic research.
- Production of large quantities of human insulin, interferons(Anti-Viral Proteins produced by Virus infected cells) human growth hormones and vaccines for foot and mouth disease of cattle (komari – in Tamil) etc.
- This technique is also employed in the transfer of genes involved in Nitrogen fixation (Nif–genes). This will help cultivators to increase productivity.

Basic techniques in Genetic Engineering

Genetic Engineering has developed after the discovery of two enzymes- the enzymes which can cut DNA into fragments and the enzymes which can join such fragments.

A. Restriction enzymes or Restriction endonucleases are molecular scissors which cut DNA at specific sites.



B. DNA ligases are the paste enzymes which help in joining the broken DNA fragments.

BIOTECHNOLOGY AND CLONING

Biotechnology uses biological organisms or biological processes through modern techniques which could be profitably used in the field of medicine, agriculture, animal husbandary and in environmental cleaning. There are several applications of Biotechnology in the field of brewing industry, enzyme technology, manufacturing of antibiotics, organic acids, vitamins, vaccines, steroids and monoclonal anti-bodies.

Brewing Industry: Fermentation of alcoholic beverages like beer, wine etc.

Enzyme Technology : Enzymes are biocatalysts that speed up reaction in cells. They can be used to catalyze the industrially important reactions and are more efficient than inorganic catalysts. Many enzymes are utilized in the pharmaceutical industry.

Antibiotics: These are substances produced by some microbes that help in increasing the immunity of human beings and which are toxic to other micro-organisms.

Organic Acids: Acetic acid is used for the production of vinegar.

Vitamins: These are chemical compounds present in variable minute quantities in natural foodstuffs. They do not furnish energy but are very essential for energy transformation and regulation of metabolism.

Edward Jenner (1749-1823)

In 1791, Edward Jenner coined the term vaccine and the term vaccination for protective i n o c u l a t i o n . Vaccines produced by Biotechnology differ from others, in that they do not contain weakened or killed agents. Instead they are so refined as to consist only of the reactive material ie., the antigen protein only. The first such vaccine was used against Hepatitis B Virus (HBV)

Vaccines: Vaccines are substances that confer immunity against specific diseases. They act as antigens and stimulate the body to manufacture antibodies.

Steroids: They are derivatives of lipids eg: Cholesterol containing steroid drugs like prednisolone, produced from the fungus Rhizopus.

Monoclonal antibodies : These are the antibodies produced from cloned cells by hybridoma technology. Monoclonal antibodies are now used in treatment of cancer.

Cloning: Cloning is an experimental technique, wherein a group of morphologically and genetically identical organisms are produced.

A clone may be defined as an exact carbon copy or copies of a single genetical parent. The word 'clone' refers only to living species. If the cloning technique is applied to veterinary science, valuable animals could be cloned from desirable adult cells.

Types of clones

Natural clones: The natural clones are formed through a natural process. (DNA replication)

Induced clones: The induced (artificial) clones are developed by nuclear transfer into the host cell. e.g. cloning of Dolly sheep.

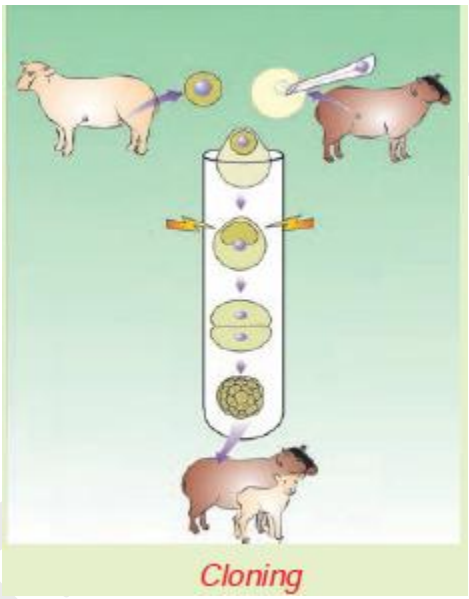
STEM CELL - ORGAN CULTURE

One of the most fascinating branches in applied embryology is stem cell culture. The stem cells are the most unspecialized mass of cells. They have two important characteristic features:

1. They have the potentiality of growing and multiplying into an enormous number of the same type of cells by repeated mitosis.

2. They can be induced to become any other type of tissue with specific functions i.e. they can be induced to become a cardiac muscle, beta cells of pancreas (which produces insulin), special neurons in brain etc.

Development of Dolly



Dolly was a cloned sheep, developed by Dr.Ian Wilmut and his colleagues in Roselind Institute in Scotland in July 1996. The scientists used the nucleus of udder cell (somatic cell taken from mammary gland) from a six year old Finn Dorset white sheep. The nucleus of the udder cell contains, diploid number(2n) of chromosomes with all the genes. They preserved the diploid nucleus in a suitable preservative. Then they took an ovum from the ovary of another sheep. The haploid nucleus (n) in the ovum was removed.

The diploid nucleus of the udder cell was injected into the cytoplasm of the enucleated ovum. Then the ovum with the diploid nucleus, was implanted into the uterus of the surrogate mother sheep. Since the ovum had the diploid nucleus, it developed into a young clone. It was named “Dolly” by Dr.Ian Wilmut.

Types of Stem Cells

There are two kinds of stem cells

1. ***Embryonic Stem Cells:*** The embryonic stem cells can be extracted from early embryo which is developed by "invitro fertilization" (fertilization done artificially in the laboratory).

After fertilization, the zygote develops into a hollow blastula by cell division. The inner mass of undifferentiated cells are isolated and they are considered as embryonic stem cells.

2. ***Adult or Somatic Stem Cells***: The body of higher animals and human beings has many well differentiated tissues like epithelial, connective, muscular, vascular, supporting, nervous and reproductive tissues. In these tissues, there are some undifferentiated cells and are considered as the adult or somatic stem cells.

They can grow, multiply and can be differentiated into same type of tissues into which they are implanted. The mechanism of adult or somatic stem cell culture is similar to that of embryonic stem cell culture. The somatic stem cells are derived from sources such as bone marrow, embryos, amniotic fluid and umbilical cord.

MICROBIAL PRODUCTION

As we discussed earlier, the field of biotechnology is very vast and has a great scope in different fields like agriculture, medicine, food industry etc. The microbial products of everyday uses are:

Vaccine: Killed or live germs suspension which is employed to induce the production of antibodies and develops immunity.

Antibiotics: Antibiotics are chemical substances derived from microbes like fungi, bacteria etc. employed to kill infectious germs (pathogens) and cure a disease.

Vitamin B12: Biotechnologically synthesized vitamin B12 is used to cure pernicious anaemia.

Enzymes: Biochemically significant enzymes are derived from microbes eg: Amylase is derived from amyloproteins of bacteria.

Insulin: Diabetes is treated by the biotechnologically produced insulin.

BIOSENSOR AND BIOCHIPS

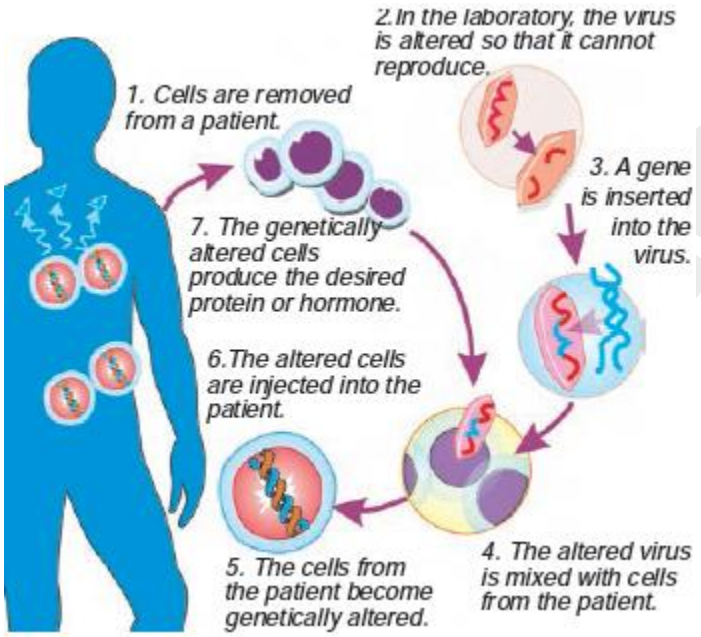
Biosensor: It is a device consisting of an immobilized layer of biological material
such as enzyme, antibody, hormone, nucleic acids, organelles or whole cells and its contact with a sensor. The sensor converts biological signals into an electrical signal. It is used in medical field and industries.

1. Blood glucose level can be detected.

2. Production of any toxin in the body due to infection can be detected.
3. Pollution in drinking water can be monitored.
4. Odour, freshness and taste of food can be measured.

Biochips

Biochips are microchips which are developed by employing techniques of Biotechnology. In future, biological computers will be developed using biochips. Biochips will be useful in defence, medicine etc.



SCIENCE TODAY – GENE THERAPY

Insulin dependent diabetes is treated with insulin injection. Insulin dependent diabetes is caused by the degeneration of beta cells of pancreas due to a
defective gene. Applying the principle of Biotechnology, it is possible to correct the defective gene. When the defective gene is corrected with a new gene, the genetic defect developed is rectified and cured.

Gene therapy is the means to treat or even cure genetic and acquired diseases like cancer and AIDS by using a normal gene to supplement or replace the
defective gene. It can be used to treat defects in Somatic i.e. (body) or gametic (sperm or egg) cell.

Types of Gene Therapy

1. Somatic gene therapy:- The defective gene in somatic cells is replaced with a corrective gene. This change is not passed to the next generation.
2. Germ line gene therapy:- Egg and sperm of the parents are changed for the purpose of passing the changes to the next generation.