MOLECULAR BASIS OF INHERITANCE
THE DNA

INTRODUCTION

Genetic Material :

It is the substance that controls the inheritance of traits from one generation to the next generation and is also able to express its effect through the formation and functioning of the traits.

Properties of Genetic Material :

As a genetic material, A molecule must fulfill the following criteria.

(i) Hereditary information must be present in the coded form in the genetic material.

(ii) The genetic material should be able to replicate and then transmitted faithfully to the next generation.

(iii) The genetic material should also be capable of variations, i.e., mutations and recombinations. These variations should be stable and inheritable.

(iv) The genetic material should be able to generate its own kind and also new kinds of molecules.

(v) Genetic material must be able to express its effect in the form of Mendelian characters.

These requirements are found in DNA thus, DNA is now recognized as genetic material.

DNA as genetic material :

(1) Direct evidences

(2) Indirect evidences

(1) Direct evidences :

(i) Transformation : It is the conversion in the genetic constitution of an organism by picking up genes present in the remains of its dead relatives.

The transformation experiments conducted by **Frederick Griffith** in 1928. He used two strains of bacterium **Diplococcus pneumoniae (Streptococcus pneumoniae).**

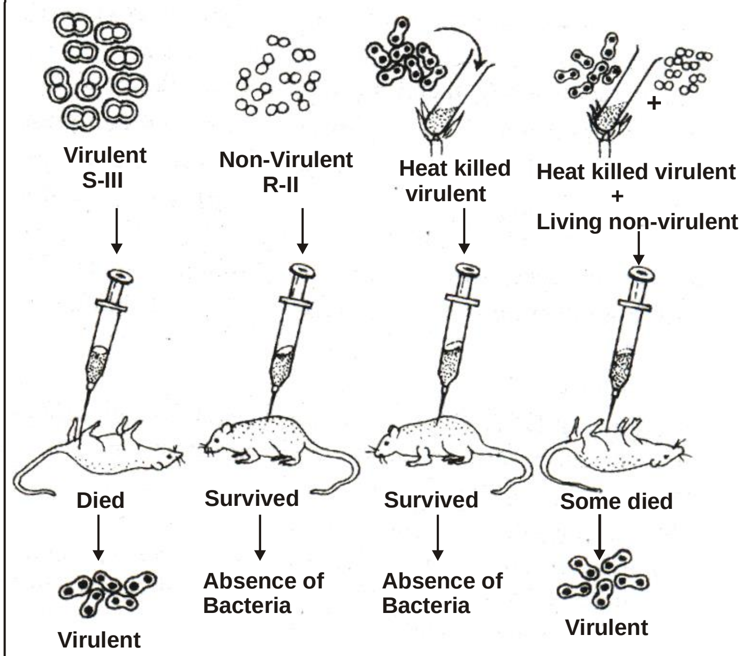

Fig. Griffith's experiments–transformation in Streptococcus pneumoniae.

(a) Smooth (S) or capsulated type which have a capsule. These bacteria are of **virulent** strain and cause **pneumonia.**

(b) Rough (R) or non-capsulated in which capsule is absent. These bacteria are of **non virulent** strain and do not cause pneumonia.

The experiment described in following four parts.

(a) When S- type bacteria injected into mice. The latter died as a result of pneumonia caused by bacteria.

(b) When R- type bacteria injected into mice. The latter lived and pneumonia was not produced.

(c) S- type bacteria which normally cause disease were heat killed and then injected into the mice. The mice lived and pneumonia was not caused.

(d) The mixed solution of Rough type bacteria (living) and smooth type heat-killed bacteria (both known not to cause disease) injected into mice.Some mice died due to pneumonia and virulent smooth type living bacteria could also be recovered from their bodies.

The fourth part of the experiment indicates that some R-type bacteria (non-virulent) were transformed into S- type of bacteria (virulent). The phenomenon is called **Griffith effect or transformation.**

Later, **Avery, Macleod and McCarty (l944)** repeated the experiment **in vitro** to identify transforming substance. They proved that this substance is in fact DNA.

They purified biochemicals from the **killed S-type bacteria** into three components – **DNA, carbohydrate and protein**.

DNA fraction was further divided into two parts: one with deoxyribonuclease or **DNase** and the **other without it.** The four components were then added to separate culture tubes containing R-type bacteria. After some time they were then analysed for bacteria.

Only DNA of S-type can changed R-type of bacteria into S-type. Therefore, the character or gene of virulence is located in DNA. Thus they proved that the chemical to be inherited is DNA and it forms the **chemical or molecular basis of heredity.**

(ii) Multiplication of Bacteriophage (Transduction) :

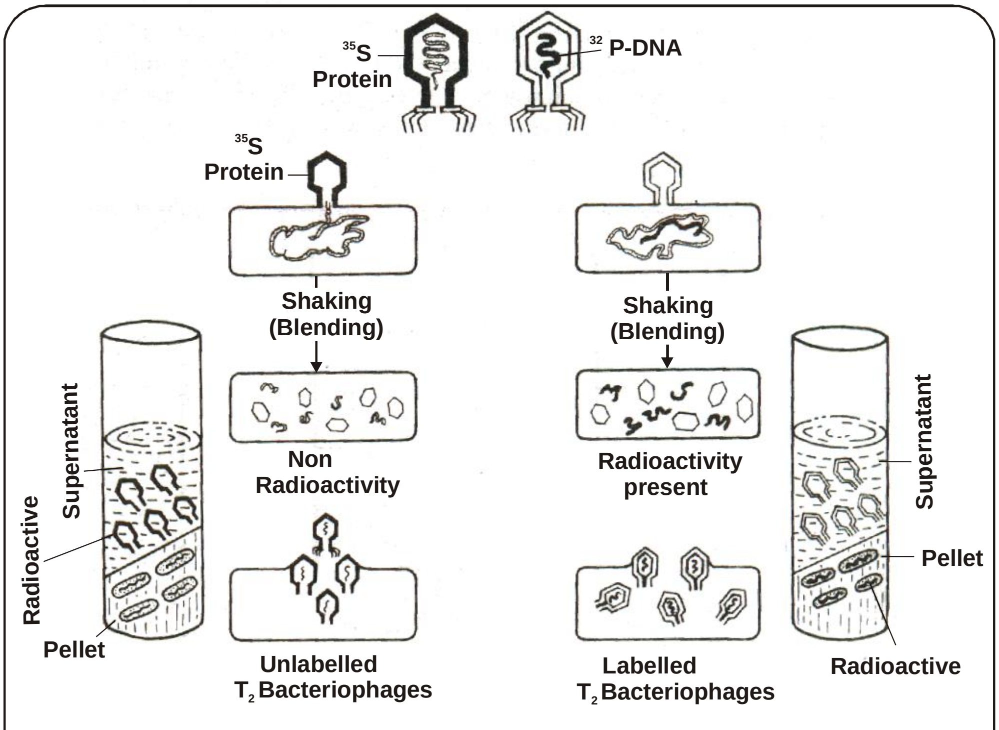

Fig. Hershey and Chase's Experiment proves that DNA is genetic material in T_2 bacteriophage

The transfer of genetic material from one bacterium to another through bacteriophage is called **transduction**. T_2 is a **Bacteriophage** which infects **E. coli.**

Hershey and Chase (1952) used radioactive phosphorus ^{32}P & radio-active sulphur ^{35}S for their experiment and proved that DNA is a genetic matarial.

Structure of Polynucleotide Chain and DNA (Introduction)

J.D. Watson and F.H.C. Crick (1953) proposed double helical structure of DNA based on the results of **M.H.F.Wilkins and co-workers.** All these three persons were awarded Nobel Prize in 1962 for this work.

The following are some of the characteristic features of double helical structure of DNA.

(1) **Each nucleotide** consists of **sugar, phosphate and a nitrogenous base**. Many such nucleotides are linked by phosphodiester bonds to form a polynucleotide chain or strand.

(2) **Phospho diester bonds** are formed between 5'carbon of sugar of one nucleotide and 3' carbon of sugar of the next nucleotide.

(3) **Nitrogenous base** is attached to **1' carbon of sugar**. At this place **purine base** is attached by its **9' position** and **pyrimidine** by its **3' position**.

(4) Polynucleotide strand is made of backbone of sugar and phosphate forming its long axis and bases at right angles to it.

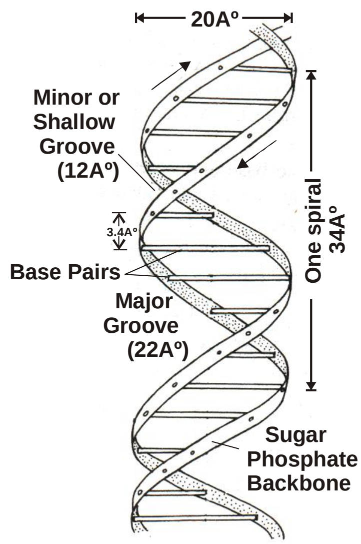

Fig. Structure of DNA- coiling in double helix of DNA

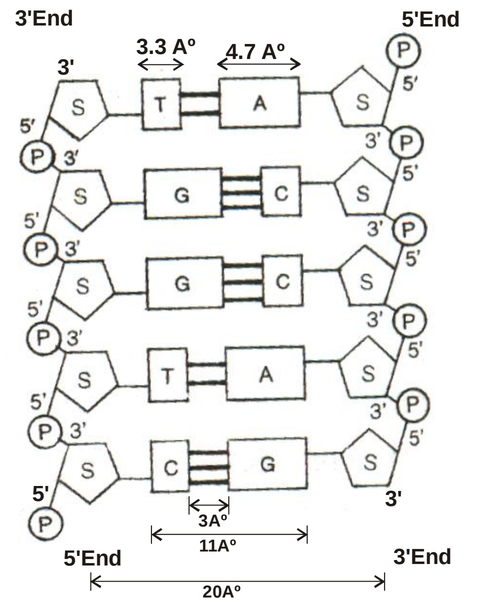

Fig. Arrangement of various Components of DNA

Chargaff (1950) made observations on the base and other contents of DNA. These observations or generalizations are called Chargaffs rule.

(i) Purine and pyrimidine base pairs are in equal amount, that is, adenine + guanine =thymine + cytosine.

(ii) Molar amount of purine-adenine is always equal to the molar amount of pyrimidine thymine. Similarly, guanine is equalled by cytosine.

(iii) Sugar deoxyribose and phosphate occur in equimolar proportions.

(iv) The ratio of A + T/G + C is constant for a species.

(5) Chargaffs rule states that in natural DNAs the base ratio AT is always close to unity and the GC ratio also to always close to unity indicated that A always pairs with T and G pairs with C. A and T, G and C, therefore,are complementary base pairs.

(6) Thus, if one DNA strand has A, the other would have T and if it has G, the other, would have C. Therefore, if the base sequence of one strand is CAT TAG GAC, the base sequence of other strand would be GTA ATC CTG. Hence, the two poly nucleotide strands are called complementary to one another.

(7) Two such complementary strands are joined with one another by hydrogen bonds between their complementary nitrogenous bases. There are three hydrogen bonds between cytosine and guanine and two hydrogen bonds between adenine and thymine.

(8) The two polynucleotide chains are helically coiled around the same axis in such a way that these can separate from one another only by uncoiling. Helical coiling is supposed to be right handed. Such a form of DNA is now called B-DNA

(9) The two chains or strands are antiparallel, i.e., they run in opposite directions in relation to their sugar molecules. Their 5'p 3' OH phosphodiester linkages are in opposite directions

(10) **Double standed DNA molecule has a diameter of 20Aº.**

(11) **The helix makes one complete turn every 34 Aº along its length.**

(12) **There are 10 nucleotides per turn of helix. Thus the distance between two neighbouring base pairs is 3.4 Aº.** Since the discovery of DNA structure, some other forms of DNA have also been recognised. These forms have been classified considering

(i) the number of base pairs per turn of helix and

(ii) the distance of base pairs along the helical axis.

Accordingly, besides commonly known B-DNA, other forms are A, C (sometimes D and E) and Z DNA. Some important similarities and differences among different types of DNA are given in.

S.No.		B	Z	A	C	D
1	Handedness of helix	Right handed	Left handed	Right handed	Right handed	Right handed
2	Pitch of helix per turn	34 Å	46 Å	25 Å	30 Å	24 Å
3	Diameter of helix	20 Å	18 Å (thinnest)	23 Å (widest)	19 Å	—
4	Stability	Stable and Physiologically active form	Unstable	Unstable	Unstable	Unstable
5	Base pairs per turn of helix	10	12 (6 dimers)	11	9.33	8
6	Distance between two base pairs	3.4Å	3.8 Å	2.5 Å	3.3 Å	3.03 Å
7	Repeating unit	Mononucleotide	Dinucleotide	Mononucleotide	Mononucleotide	Mononucleoide