Cytoplasmic inheritance

Besides chromosomes, various organelles of cytoplasm also contain DNA. The mitochondria and plastids have their own DNA and carry their genetic characters themselves. The mechanism in which cytoplasmic inclusions (e.g., alpha, beta, sigma and kappa particles) and organelles (plastids, mitochondria, centriole, etc) take part in transmission of characters from generation to generation is called cytoplasmic inheritance. Since cytoplasmic inheritance is based on cytoplasmic DNA molecules, it is also called extra chromosomal inheritance.

The smaller inheritable extra chromosomal unit is called as **plasma gene** and all the plasmagenes of a cell constitute the **Plasmon** (like the genome). Cytoplasmic inheritance is due to the plasmagenes located in cell organelles that are integral constituents of normal cells. The characteristic features of this inheritance are summarized below.

1. Different in reciprocal crosses

In Mendelian inheritance, the results of reciprocal crosses are identical (one exceptional – sex linked inheritance). If the character is transmitted through cytoplasm, the reciprocal cross results will be different.

2. Somatic segregation

Plasma genes generally show somatic segregation during mitosis, a feature of rare occurrence in the case of nuclear genes.

3. Non-mappability

Gene controlled characters shows linkages and hence they are mappable. But the characters transmitted through cytoplasm show no linkage. Hence, they are not mappable.

4. Non-Segregation

Segregation is typical of Mendalian heredity. The cytoplasmic heredity fails to show segregation. Sometimes, segregation may occur in cytoplasmic heredity also. But it will not be consistent with the segregation of chromosomes.

5. Indifference to nuclear substitution

When the nucleus is transplanted, no change is found in the cytoplasmic inheritance.

6. Infection like transmission

Cytoplasmic inheritance seems like infection through some agents.

Maternal inheritance

Maternal effects are produced due to the influence of mother's nuclear genotype on the phenotype of its progeny and last for one generation. Characters showing the maternal effect exhibit clear-cut differences in F1 for reciprocal crosses. One of the examples for maternal effect is coiling pattern of shell in snail limnaea. In this snail, the direction of coiling of its shell is controlled by single nuclear gene D/d; the dominant allele D produces right-handed coiling, while its recessive allele d produces left-handed coiling. The direction of shell coiling in an individual is governed by the genotype of its female parent and not by its own genotype. As a result, reciprocal crosses show differences in coiling in F1 and there is no phenotypic

segregation in F2 the phenotypic effect of segregation is observable in F3 only. Crosses between females with left-handed coil (dd) and males having right handed coil (DD) produce F1 progeny (Dd) with left-handed coil, since the genotype of the female parent is dd. In F2 segregation of Dd produces three genotypes (DD, Dd, dd) in the ratio of 1:2:1. But the F2 snails with DD, Dd as well as dd genotypes exhibit right handed coiling since their female parent has the genotype Dd which determines right-handed coiling in the progeny (irrespective of the genotypes of the progeny). The F3 progeny from the F2 individuals with the genotypes DD and Dd will show

right handed coiling, while those from dd F2 individuals will exhibit left-handed coiling of their shells; thus produces the typical 3:1 ratio in F3.
The reciprocal cross (DD x dd), on the other hand, yields right-handed coiling in the F1 (Dd) as well as in the three genotypes, 1DD:2Dd:1dd, obtained in the F2. But in F3 2/3 of the progenies show right-handed coiling since they are derived from F2 individuals having the genotypes DD and Dd. The remaining 1/3 of the F3 progenies exhibit left handed coiling since their female parents had the genotype dd; this yield the typical monohybrid ratio of 3:1 in the F3.
The direction of coiling in this snail is determined by the plane or the direction of the first mitotic division of the zygote. The plane of the first division, of the other hand, is determined by some substances already present in the egg cell. Obviously, these substances are produced by the female parent; as a result, they would produce the phenotype appropriate for the maternal genotype. Further, genotype of the zygote itself has no effect of the plane of first division and consequently, on the direction coiling since its gene products are not involved in determining this trait. As a result, the direction of coiling in an individual is governed by the genotype of its female parent. Therefore, phenotypes appear one generation later than the appearance of the concerned genotypes, producing delayed segregation in F3.

Inheritance of kappa particles in Paramecium

There are two types of strains in ***Paramecium***. One has kappa particles in its cytoplasm and other does not have such particles in its cytoplasm. The presence of kappa particles in the cytoplasm leads to production of a toxin known as paramecin. This toxin can kill the strain Paramecium that lacks kappa particle. Thus the strain with kappa particle is known as killer strain and that without kappa particle is called as sensitive strain. The production of kappa particles is dependent on a dominant allele K, so that the killer strains are KK or Kk and sensitive strains are ordinally kk. In the absence of dominant allele K, kappa particles can not multiply and in the absence of kappa particles, dominant allele K cannot produce them de novo.
If the killer (KK) and sensitive (kk) strains are allowed to conjugate, all exconjugants (the cells separating after conjugation) will have the same genotype Kk. The phenotypes of these exconjugants will however depend upon duration for which conjugation is allowed. If conjugation does not persist long enough for exchange of cytoplasm, heterozygote (Kk) exconjugants will only have parental phenotypes. It means that killers will remain as killers and sensitive will remain as sensitive after conjugation. If conjugation persists, sensitive stain will receive kappa particles and will become killer, so that exconjugants will be killers having genotype Kk.

Plastid inheritance

Plastids are minute cytoplasmic organelles in plant cells. Most important are the chloroplastids, which carry chlorophyll. Plastids arise from smaller cytoplasmic particles (plastid primordial) that contain DNA. They duplicate themselves independently. They are transmitted through the cytoplasm of the egg.
The Four-O'clock plant, *mirabilis jalapa*, has branches that produce either green, white or mixed green-white (variegated) leaves. In crosses between flowers of these branches, the offspring are all green if the maternal parent is a flower from a green branch. Such offspring remain green throughout subsequent generations as long as maternal plant is green. Similarly, as long as the maternal parent is from a white branch, the offspring are all white. When variegated branches are used as female source, both green and plastids are present in cells of female parent. Therefore, female gametes may carry either green or pale plastids or both. Consequently, three kinds of

plants namely green, pale and variegated plants would be obtained.

Inheritance of leaf colour in *Mirabilis jalapa*

Egg source	Pollen Source	Progeny
White	Green Variegated White	White
Green	Green Variegated White	Green
Variegated	Green Variegated White	White Green Variegated

Plasmids:

Plasmids are called episomes. They are extra chromosomal, circular, covalently closed double stranded DNA molecules found in bacteria. In effect, plasmids are accessory chromosomes. Plasmids can replicate autonomously of the host chromosome. The size of plasmid ranges from two to several hundred kilobases. Plasmids carry genes for the inactivation of antibiotics, metabolism of natural products and production of toxins. The F factors and R factors are important plasmids of *Escherichia coli.*

Mitochondria (mt DNA)

Mitochondria are present in living organisms arise from pre existing mitochondria. They are small cytoplasmic organelles present in animal and plant cells but not present in bacteria and viruses. Mitochondria provide cellular energy through oxidative phosphorylation. Mitochondria contain a small circular DNA molecule codes for limited number of structures and functions. The size of mtDNA ranges from about 16 kb in mammals upto several hundred kilo base pairs in higher plants (eg 570 kb in maize) and mt DNA usually found in multiple copies per organelle. The mtDNA play a significant role in crop improvement. Recent evidences showed that the cytoplasmic genetic male sterility system in crop plants is due to the interaction of mitochondrial genome to the nuclear genome.

Chloroplast DNA

Chloroplast of the plant cell contain circular DNA molecule which are selfreplicating in nature. The isolated chloroplast found to be capable of protein synthesis in the presence of light. The DNA analysis revealed that 30-60 copies of the chloroplast genome are found in each chloroplast of higher plants. The chloroplast genome contains herbicidal resistant and streptomycin resistant genes.