

14. CYTOPLASMIC INHERITANCE

Inheritance due to genes located in cytoplasm (plasmagenes) is called cytoplasmic inheritance. Since genes governing traits showing cytoplasmic inheritance are located outside the nucleus and in the cytoplasm, they are referred to as plasmagenes. The sum total of genes present in the cytoplasm of a cell or an individual is known as plasmon. The plasmagenes are located in DNA present in mitochondria (mt DNA) and in chloroplasts (cp DNA). Together both the DNAs are called organelle DNA. Therefore, this type of inheritance is often referred to as organellar inheritance, plastid inheritance or mitochondrial inheritance. In this, generally, the character of only one of the two parents (usually female) is transmitted to the progeny. Hence such inheritance is usually referred to as extra - nuclear or extra-chromosomal or maternal or uniparental inheritance.

The cytoplasmic inheritance is of two types: 1) Plastid inheritance and 2) mitochondrial inheritance.

1. Plastidial or chloroplast inheritance: Plastids self-duplicated and have some amount of DNA and plays an important role in cytoplasmic inheritance. Plastids have green pigments called chloroplasts. Chloroplasts contain a unique circular DNA (cp DNA) in the stroma that is completely different from the nuclear genome. Some examples of plastid inheritance

are given below:

a) Leaf variegation in *Mirabilis jalapa*: The conclusive evidence for cytoplasmic inheritance was first presented by C. Correns in *Mirabilis jalapa* (Four 'O' clock plant) in 1909. He studied inheritance of leaf variegation in *M. jalapa*. Variegation refers to the presence of white or yellow spots of variable size on the green background of leaves. In *M. jalapa*, leaves may be green, white or variegated. Some branches may have only green, only white or only variegated leaves. Correns made crosses in all possible combinations among the flowers produced on these three types of branches. When flowers from green branch were used as female parent, all the progeny were green irrespective of the phenotype (green, white or variegated) of male parent. Similarly, progeny from crosses involving flowers bloomed on white branches as female parent were all white irrespective of the phenotype of male parent. But in progeny from all crosses involving flowers born on variegated branches as female parent, all the three types i.e. green, white and variegated individuals were recovered in variable proportions.

Female Parent X Male Parent

Green x Green
 x White **Green**
 x Variegated

White x Green
 x White **Pale green**
 x Variegated

Variegated x Green
 x White Green, white and variegated in variable ratio in each of the cases
 x Variegated

The green leaf branches have normal chloroplasts, white branches have mutant chloroplasts and variegated have a mixture of both normal and mutant chloroplasts. The above results indicated that the inheritance is governed by chloroplasts. Since the cytoplasm is contributed to the zygote mainly by female parent, the plastids are transmitted to the zygote from the female parent. Thus the plastids are responsible for variation in the crosses of green, white and variegated leaves.

b) Iojap in maize: In maize, there are three types of leaves i.e. green, iojap (green and white stripes) and white. The green leaves have normal plastids. Iojap leaves have a mixture of normal and mutant plastids and white leaves have only mutant plastids. In a cross between green female and iojap male, only green individuals are produced in F1 generation. But in the reciprocal cross (iojap female and green male) all the three kinds of progeny are obtained in variable proportions in F1.

Parents	Female x Male
Phenotype	Green x Iojap
	↓
Generation	F1
	Green

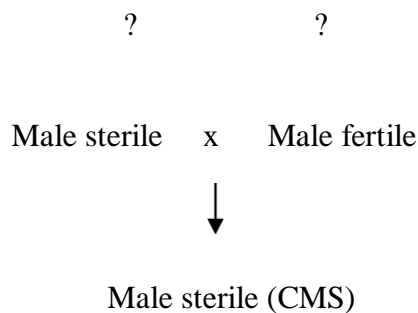
Reciprocal cross

Parents	Female	x	Male
Phenotype	Iojap	x	Green
		↓	
Generation	F1		
	Green, Iojap, White in variable proportion		

These reciprocal differences can be attributed to the type of plastids in the egg cell since only female parent is contributing cytoplasm to the zygote.

2. Mitochondrial inheritance: The inheritance of some characters, such as cytoplasmic male sterility in plants, pokyness in *Neurospora* etc., is governed by mitochondrial DNA (mtDNA).

- a) **Cytoplasmic Male Sterility (CMS) in maize:** In several crops, cytoplasmic control of male sterility is known. In maize, cytoplasmic male sterility (CMS) is governed by mitochondrial DNA. In such cases, if female parent is male sterile, F1 progeny also will be male sterile, because cytoplasm is mainly derived from female parent.



- b) **Pokyness in *Neurospora*:** *Neurospora*, which is a breadmould has two strains i.e. wild and poky. The wild strain has normal growth. While the poky which is a mutant has very slow growth. A cross between a poky female and a wild male produce only poky progeny. In reciprocal cross (a cross between wild female and poky male) all the progeny would be wild. This suggests the

presence of cytoplasmic inheritance because only difference between the reciprocal crosses is in the main contributor of cytoplasm.

Reciprocal cross



Characteristic features of cytoplasmic inheritance

- 1. Reciprocal difference:** Reciprocal crosses show marked differences for characters governed by plasmagenes. In most cases, plasmagenes from only female parent are transmitted and hence this phenomenon is also called uniparental inheritance.
- 2. Lack of segregation:** In general, F₁, F₂, F₃ and subsequent generations do not show segregation for a cytoplasmically inherited trait, as F₁ individuals receive plasmagenes from female parent only.
- 3. Somatic segregation:** Plasmagenes generally show the features in somatic tissues such as leaf variegation features which is of rare occurrence in case of nuclear genes.
- 4. Association with organelle DNA:** Several plasmagenes have been shown to be associated either with chloroplast or mitochondrial DNA. For example: Cytoplasmic Male Sterility (CMS) in sorghum and maize is associated with mitochondrial DNA.
- 5. Nuclear transplantation:** Nuclear transplantation means nucleus of a cell is removed and replaced by nucleus of another genotype from a different cell. If nuclear transplantation reveals a trait to be governed by genotype of cytoplasm and not by that of nucleus, it clearly indicates that the trait or character is governed by cytoplasmic inheritance.
- 6. Mutagenesis:** Some mutagens are highly specific mutagens which act only on the plasmagenes and do not affect nuclear genes Eg; ethidium bromide,

Induction of mutations by such agents or chemicals in a gene clearly indicates that it is a plasmagene.

7. **Lack of chromosomal location:** In many organisms, extensive linkage maps of nuclear genes are available. If a gene is shown to be located in one of these linkage groups, obviously it cannot be a plasmagene.
8. **Transfer of nuclear genome through back crosses:** Nucleus of a variety or species may be transferred into cytoplasm of another variety or species through repeated back crossing with former, which is used as recurrent male parent. Lines produced in this way are called alloplasmic lines, since they have cytoplasm and nucleus from different species.
9. **Lack of association with a parasite or symbiont or virus:** Only those cytoplasmically inherited traits which are not associated with parasites, symbionts or viruses can be regarded to be governed by plasmagenes.

Differences between chromosomal (nuclear) and extra-chromosomal (cytoplasmic or extra-nuclear or maternal) inheritance

S.No.	Character	Chromosomal inheritance	Extra-chromosomal inheritance
1	Location of hereditary factors	Nucleus	Cytoplasm
2	Associated with	Chromosomes	Chloroplasts and mitochondria
3	Pattern of Inheritance	Can be explained by mendelism	Cannot be explained by mendelism
4	Individual hereditary factors are known as	Genes	Plasmagenes
5	Hereditary factors are collectively known as	Genome	Plasmon
6	Characters of F ₁ progeny	May show dominance or may be intermediate between the parents	Exhibits only the characteristic of the female parent
7	Reciprocal differences	Not observed	Observed
8	Segregation of factors and recombination	Present	Absent
9	Attributes of progeny	Under the control of them own genes	Under the control of cytoplasm of female parent
10	Action of mutagen	Non-specific	Very specific
11	Frequency of occurrence	Most common	Rare
12	Gene mapping	Easy	Difficult

