CYTOPLASMIC INHERITANCE

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CYTOPLASMIC INHERITANCE

- Cytoplasmic inheritance was discovered by Correns (1908) in Mirabilis jalappa (Four O'clock plant), and by Baur (1908) in Pelargonium zonale, and Jenkins (1924) described the iojap leaf variegation in maize.
- Rhoades (1933) described cytoplasmic male sterility in maize.
- Ruth Sager (1954) described cytoplasmic (uniparental) inheritance of streptomycin resistance in Chlamydomonas.
- The character of only one of the two parents (usually female parent) is transmitted to the progeny, is called cytoplasmic inheritance. Such inheritance is also called to as extranuclear inheritance, extrachromosomal inheritance, and maternal inheritance.
- Cytoplasmic genes are located outside the nucleus, and in the cytoplasm, it is referred to as plasma gene, cytogenes, extranuclear gene, and extrachromosomal gene.
- Sum total of genes present in the cytoplasm of a cell, is called plasmon, while all the genes present in a plastid, is called plaston.
- When plasma genes are located in the DNA of mitochondria, called mt DNA, and in chloroplast, called cp DNA. Togather the mt DNA and cp DNA are termed as organelle DNA.
- The cytoplasm minus mitochondria and chloroplast is known as cytosol.
- Cytoplasm - (mitochondria + chloroplast) = cytosol
- If the individuals heterozygous for plasma genes are called cytohets (cytoplasmic heterozygotes).

CHARATERISTIC OF CYTOPLASMIC INHERITANCE

- The characters of plasma genes are transferred only from female parent to the progeny. This phenomenon is called uniparental inheritance.
- There is a lack of segregation in the F2 and subsequent generation.
- If the plasma genes are transferred from both the parent to the progeny, it is called biparental inheritance.
- Plasma genes generally show somatic segregation during mitosis.
- Several plasma genes have been shown to be associated with cpDNA or mtDNA, e.g., streptomycin resistance with cpDNA in Chlamydomonas, and male sterility with mtDNA in maize and jowar.
- In case of nuclear transplantation, nucleus of a cell is removed and replaced by a nucleus of another genotype from a different cell.
- Nucleus of a variety or species may be transferred into the cytoplasm of another variety or species through repeated back cross.
- Some mutagens, i.e., ethidium bromide are highly specific mutagens for plasma genes, while nuclear genes are not affected by them.
- In many cases, cytoplasmically inherited characters is associated with a parasite, symbiont or virus present in the cytoplasm of the organism.

A. PLASTID INHERITANCE

- The inheritance of plastid characters due to plasma genes located in the plastid is called plastid inheritance.
- Correns and Bour (1908) studies the plastid inheritance on chlorophyll variegation in leaves. Variegation refers to the white or yellow spots of variable size on the green background of leaves.
- Variegation may be produced by environmental factors, nuclear genes or plasma genes.
- Mutant plasma genes affecting chloroplast are known in many crop plants, e.g., barley, wheat, oat, maize, jowar, pea, tobacco, tomato, lettuce, sugarbeat, chillies and many ornamental plants.
- In mirabilis jalapa (uniparental transmition)
- Correns made reciprocal crosses in all combination among the flowers produced three types of branches of mirabilis jalapa such as green, white and variegation.
- Flowers from a green branch use as female were crossed to green, white and variegation used as male parents, and all progeny were produced green.
- Similarlly, flower from white branches used as female parent were crossed to green, white and variegation used as males parent which produced all the progeny white.
- But when flower from variegation branches used as female were crossed to green, white and variegation used as males parent. They were recovered in variable progenies which are given below:

Leaf phenotype of the branch used as female parent	Leaf phenotype of the branch used as male parent	Leaf phenotype of the progeny (F1)
Green	1. Green	Green
	2. White	Green
	3. Variegation	Green
White	1. Green	White
	2. White	White
	3. Variegation	White
Variegation	1.Green	Green, white and variegated in variable ratios in each of the three cases
	2. White	
	3. Variegation	

- Therefore, all phenotype of progenies would be same as that of female parent, except when the variegated branch were used as female parent.
- The result obtained from various crosses in mirabilis jalapa. Green leaves have normal chloroplast, and white leaves have only abnormal chloroplast. But in case of variegated leaves, green sectors have normal chloroplast, white sectors have abnormal chloroplast.
- Egg cells produced om a green branches will have normal proplastids, while sperms produced green, white or variegated branches will contribute no plastid to the zygotes.
- Therefore, progeny from three crosses using flowers from the green branches as females will produce all green. Similarly, progeny from the three crosses involving flowers on the white branches as female will all be white, since the zygotes from these crosses will receive only the abnormal proplastids through egg cells.
- However, cells in branches have variegated leaves may have only normal proplastid in green sectors, only abnormal proplastid in white sectors or both types (normal and abnormal proplastid.

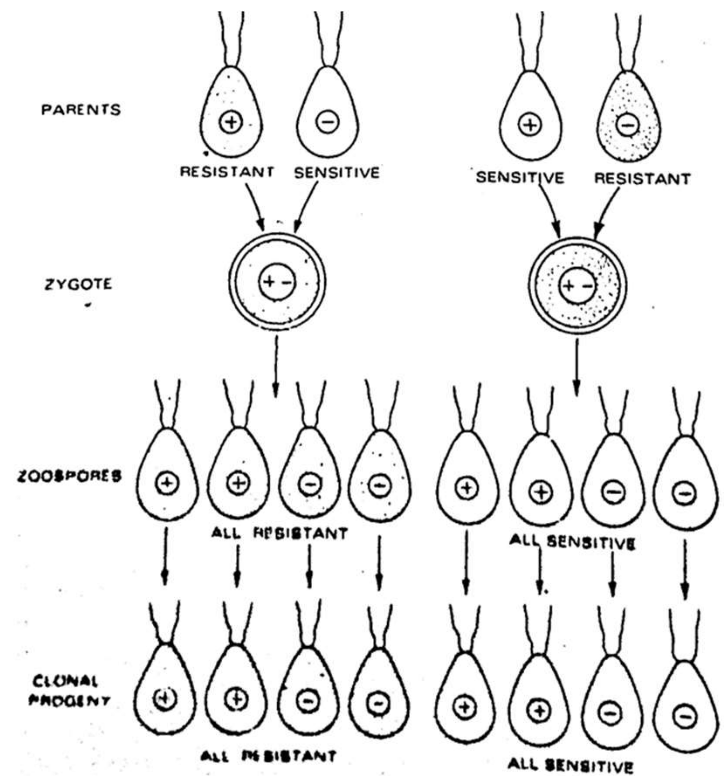
2. Pelargonium zonale:

Biparental transmission of plasma genes was demonstrated by Baur (1908) in pelargonium. Both male and female parents contribute plasma genes to the zygote. As a result, green, white and variegated progeny derived from vast majority of reciprocal crosses may be similar.

3. Chlamydomonas Reinhardtii (Green algae)

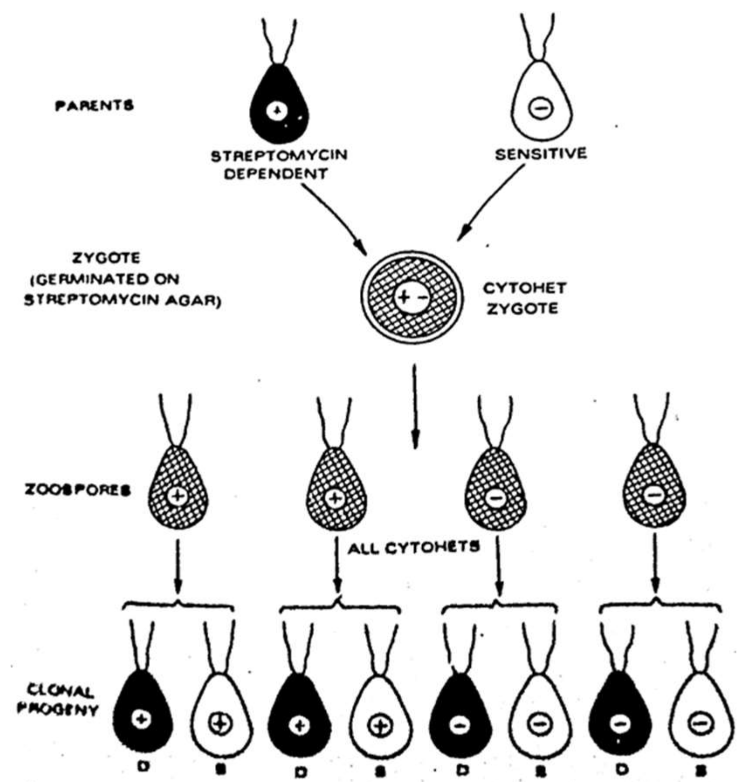
(a) Uniparental transmission

- Transmission of plasma genes of Chlamydomonas have been investigated by Sager and co-workers.
- Plasma genes such as streptomycin resistance, erythromycin resistance, acetate dependence, etc. are located in cpDNA.
- Chlamydomonas is haploid (n). It has two mating type say + and -. Both mating type are controlled by two alleles, say mt+ and mt- of a gene.
- During conjugation, mt+ and mt- cells are fuse together. Cytoplasm of both cells present in equal quantity in zygote.
- The plasma genes of mt- parent is inactive, while plasma gene of mt+ parent is active in the zygote.
- The zygote undergoes meiosis to produce 4 or 8 haploid zoospores. The zoospores show segregation of nuclear gene from which all the zoospores are identical in clonal progenies.
- Mating between mt+ streptomycin resistance and mt- susceptible cells produce only resistance progeny. But the reciprocal mating (mt+ susceptible and mt- resistance) produce susceptible progeny.
- Because, plasma gene of mt- is inactivated by the plasma gene of mt+.



(b) In biparental transmission

- In case of less than 1% of zygotes, plasma genes of mt- parent are active and produce cytohets zygote.
- The frequency of cytohets can be increase by exposing mt+ parent due to used an appropriate dose of UV rays before mating.
- Meiosis in cytohet zygotes produces cytohet zoospores.
- But somatic segregation of plasma genes occur during clonal growth through mitosis, producing an approximately 1: 1 ratio of streptomycin dependent and streptomycin sensitive.



B. MITOCHONDRIAL INHERITANCE

- Mitochondria originate from pre-existing mitochondria only, and contain DNA, called mtDNA. Many plasma genes are located in mtDNA.
- Generally mitochondria from only one of the parents are transmitted to the progeny. Therefore, characters controlled by the genes located in the mtDNA show cytoplasmic inheritance.
- In Culex mosquitoes, The male sterility is governed by mt DNA.
- Streptomycin resistance in paramecium is determined by a mtDNA.
- Cytoplasmic male sterility is controlled by mtDNA in maize, jowar and several other plants.

Cytoplasmic male sterility (CMS):

- CMS is produced by plasma genes located in the mtDNA or cpDNA.
- CMS shows typical cytoplasmic inheritance. If a male sterile plant crossed with male fertile plant, produced all male sterile progeny. The male sterile line is maintained by sib mating with male fertile line in every generation. In such situation, the male fertile line is referred to as maintainer line (B-line). Male sterile line is known as A-line.
- CMS line is extensively used in hybrid seed production in maize, jowar, bajra, rice, etc.
- There are three distinct CMS cytoplasm in maize such as cms-T, cms-C and cms-S.
- The recessive gene in nucleus is called non-restorer gene, and dominant gene called restorer gene. The restorer gene affects to cms which become male fertile.
- So that individual having a restorer gene in heterozygous or homozygous state are male fertile even in presence of cms cytoplasm.
- The most restorer genes are sporophytic in action, i.e., Function of pollen depends on the genotype of plant producing the pollen and not on the genotype of the pollen itself.
- But Rf3 in maize has a gametophytic action so that Rf3 rf3 heterozygotes produce 50% viable (Rf3) and 50% dead (rf3) pollen grain.

Male sterile line	Male fertile line	Progenies
[rr] S	[rr] F	[rr] S
[rr] S	[RR] F	[Rr] F
[rr] S	[Rr] F	1 [rr] S : 1 [Rr] F

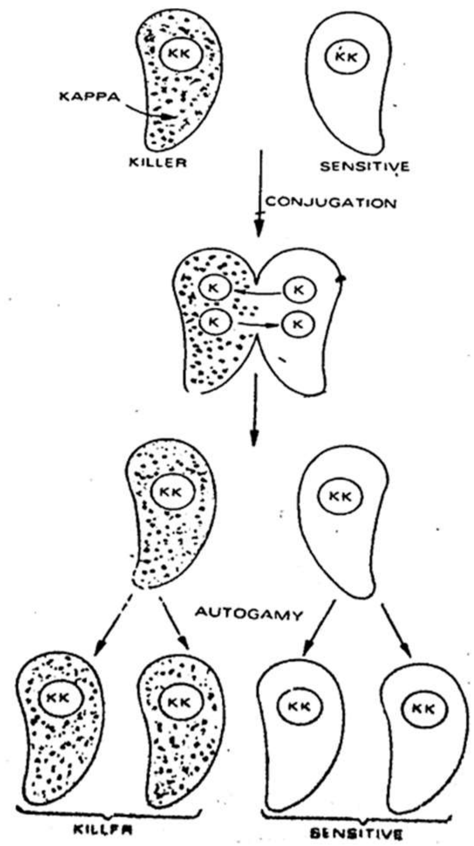
Symbionts

- Paramecium aurelia is a unicellular animal and their cytoplasm contain kappa particles. These particles are symbiotic bacteria (Caedobacter taeniospiralis).

- There are two types of kappa particles such as (i) bright, and (ii) non-bright.
- In paramecium, about 20% of kappa particles are bright. Bright kappa particles are believed to produce a toxin (paramicin) which is lethal to sensitive paramecium.
- All paramecium lacking kappa are sensitive, while those paramecium containing kappa are resistance to the paramicin.
- Generally, killer paramecium produce the toxin only when the number of kappa particles is 400 or more. Such paramecium is kill to sensitive paramecium.

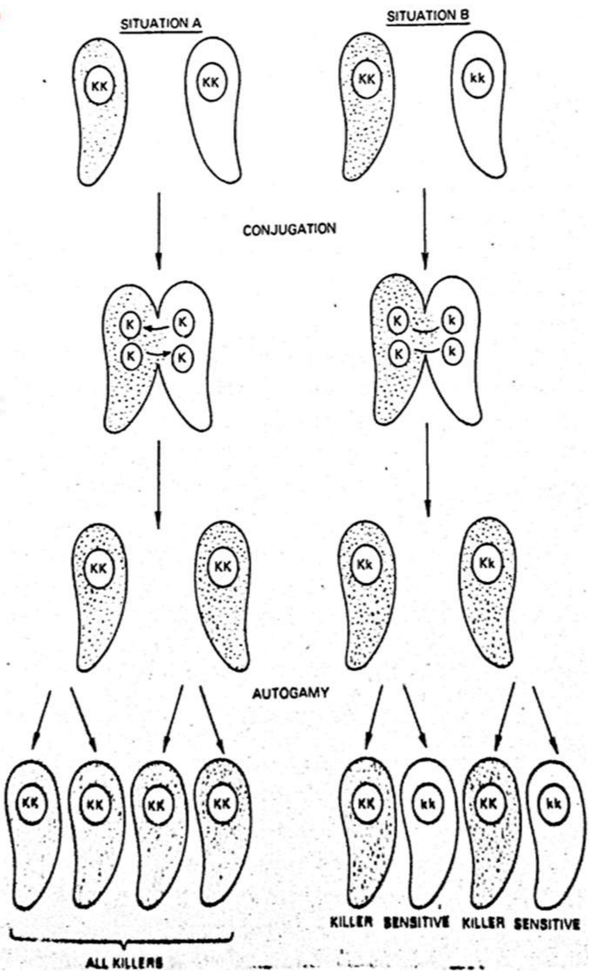
1. CONJUGATION OF PARAMECIUM WITHOUT EXCHANGE OF CYTOPLASM:

- Kappa particles show cytoplasmic transmission as like to plasma genes
- Generally, there is no cytoplasmic exchange accompanying exchange of nuclei during conjugation in paramecium.
- Therefore, during conjugation between one killer and one sensitive paramecium, the sensitive paramecium does not receive any kappa particle. As a result, the sensitive paramecium remains sensitive after the conjugation and produces sensitive progenies.



2. Consequences of occasional cytoplasmic exchange during conjugation

- Kappa particles may be multiply through fission which depends on the presence of a dominant nuclear gene K.



- Kappa particles are able to multiply only in the paramecium having the genotype KK or Kk. In kk paramecium, kappa particles are unable to multiply.
- As a result, they are limited through dilution following several binary fission of such paramecium.
- Thus killer paramecium with kk genotype become sensitive due to a loss of their kappa particles.

(i) Situation-A

- Sometime, cytoplasm exchange does occur during conjugation in paramecium.
- When cytoplasm exchange take place during conjugation between a killer and a sensitive paramecium, both exconjugants receive kappa particles.
- If both killer and sensitive paramecium have nuclear gene KK, both the exconjugant animal will have genotype KK and will become killers.
- Therefore, autogamy in such exconjugants produces only KK progeny, all of which retain kappa and the killer trait.

(ii) Situation-B

- When the killer paramecium has the genotype KK and the sensitive paramecium is kk, the two exconjugants will have the genotype Kk.
- If the cytoplasmic exchange occurs in such a conjugation, the two paramecium will receive kappa particles and therefore, will become killer.
- Autogamy in these exconjugant produce two types of progeny (50%KK and 50%kk).
- Kappa particles will multiply normally in paramecium of the genotype KK and they will remain killers.
- However, kappa particles will be unable to multiply in paramecium having the genotype kk,
- As a result, kappa particle disappear from such paramecium after several division (binary fission).

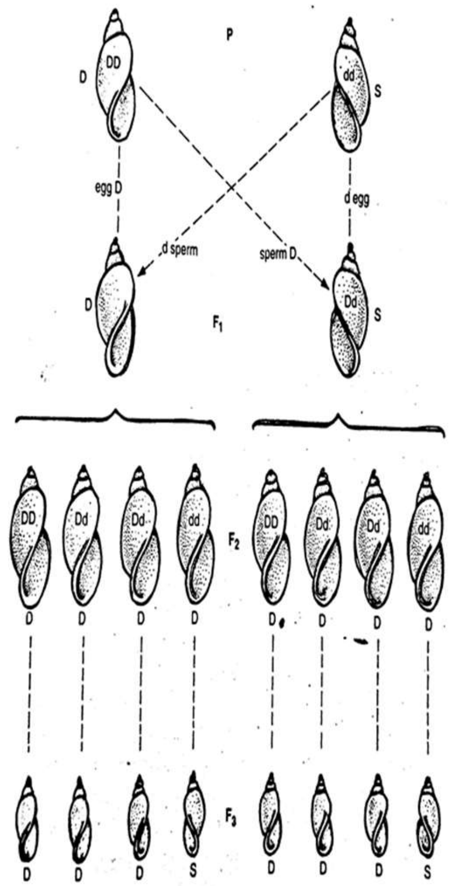
Maternal effect

- **The development of some characters in several organism is either governed by the genotype of the female parent, is known as maternal effect.**
- **Such characters are controlled by nuclear genes.**

- **Example: Snail limnea**
- **The direction of coiling of snail shall is governed by a single nuclear gene D/d. Dominant allele D produce right handed coiling, while recessive allele d produces left handed coiling. The direction of shall coiling in an individual is controlled by a genotype of female parent, and not by it own genotype.**
- **Left handed coil (dd) as female is crossed to right handed coil (DD) as male, produce F1 progeny with left handed coil (Dd). In f2 progenies, Dd F1 progeny produces three genotype in 1 DD : 2 Dd : 1 dd ratio which are exhibit right handed coiling. Since their female parent has the genotype Dd which determined right handed coiling in the progeny.**
- **F3 progeny from F2 individual with the genotype DD and Dd will show right handed coiling, while those from dd F2 individual exhibit left handed coiling of their shall. This produce the typical ratio 3 : 1 (right : left handed) in F3 progeny.**
- **In the reciprocal crosses, right handed coiling DD female is crossed to left handed coiling dd male, produced right handed coiling Dd in F1 progeny, as well as in the three genotypes 1 DD : 2 Dd : 1 dd obtained in F2 progeny.**
- **But in F3 progeny, 2/3 of the progenies show right handed coiling which are derived from F2 individual having the genotype DD and Dd. The remaining 1/3 of the F3 progeny exhibit left handed coiling. They are produce typical monohybrid ratio of 3 : 1 (right : left handed) in the F3.**
- **The inheritance of shall coiling of snail may be summarised as follows:**

1. **F1's from reciprocal crosses show differences in coiling pattern.**
2. **Homozygous coiling in F2, i.e., no segregation in F2 generation.**
3. **Appearance of the typical 3 : 1 ratio in F3.**

- **The 3 : 1 ratio in F3 clearly indicates that coiling of shall is governed by a single nuclear gene, but the segregation of this nuclear gene is apparently delayed by one generation.**
- **This is because the direction of coiling in snail is determined by the direction of the first meiotic division of the zygotes.**
- **On the other hand, the direction of first meiotic division is determined by some substances which are already present in egg cell, these substance are produce by the female parent, as a result, they would produce the phenotype appropriate by the female parent.**



Iojap variegation in maize

- Some nuclear gene influence the expression of plasma genes, but there is little. The expression of plasma genes is associated with either mitochondria or plastid which is greatly modified by nuclear genes.

- A classical example of interaction between nuclear and cytoplasmic genomes or between cms restorer gene in maize.
- Variegation (iojop) is produce by a recessive nuclear gene ij in plant homozygous for (ij ij). But once this variegation is produced by the nuclear gene ij, it show a typical cytoplasmic inheritance.
- Clearly, the nuclear genotype ij ij has a mutagenic effect on the plasmid genome. Once this mutation is produced in some cpDNA molecules, the variegation is inherited cytoplasmically.
- The cross between normal plant (Ij Ij) as female and iojop plant (ij ij) as male, produces all green plants in F1 with the nuclear genotype (Ij ij).
- In F2 generation, ¼ progenies are ij ij and develop the iojop variegation, the remaining ¾ progenies are normal green.
- When the iojop F2 plant as male are crossed with normal green plants as female, a marked reciprocal differences is observed in the progeny, and all progeny are normal green.
- But in the reciprocal crosses, green, white and iojop progeny are recovered.
- The ratio between the three types of progeny is quite variable.