TOPIC:CYTOPLASMIC INHERITANCE
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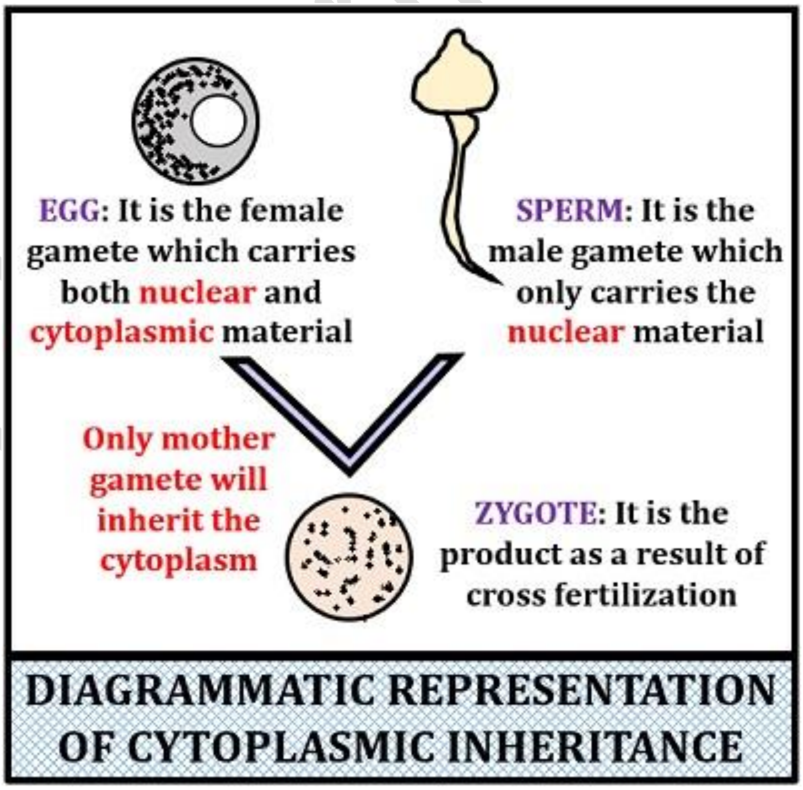
CYTOPLASMIC INHERITANCE

Synonyms: Extranuclear inheritance
Maternal inheritance
Extrachromosmal inheritance

Cytoplamic inheritance is the transmission of genes that occur outside the nucleus. It is found in most eukaryotes and is commonly known to occur in cytoplasmic organelles such as mitochondria and chloroplasts.These two autonomous cell organells have their own genetic material.
The gamete which contribute the cytoplasm in zygote is only egg. Male gamete brings only nuclear material. There is no cytoplasm which is contributed by male gamete. That means whatever cytoplasm is present in zygote is contributed by female gamete.Here cytoplasmic inheritance is coming from mother i.e. maternal side, that’s why so many times it is also termed as maternal inheritance.



DIAGRAMMATIC REPRESENTATION OF CYTOPLASMIC INHERITANCE

Few important examples of extranuclear inheritance are stated under some classified subheadings:

I.Plastid inheritance in *Mirabilis jalapa* (4'o clock plant):

Correns (I908) worked out the plastid inheritance in ***Mirabilis jalapa***. The plant shows three types of branching:

- Branches with green leaves: due to presence of chloroplast
- Branches with white leaves: due to presence of leucoplast
- Branches with variegated leaves: due to presence of chloroplast,leucoplast and chromoplast.

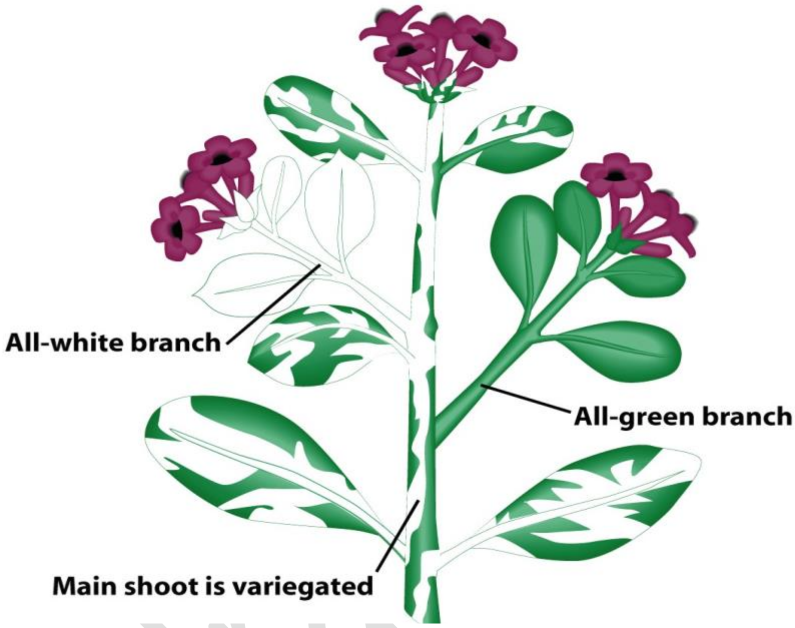


Figure: Leaf variegation *in Mirabilis jalapa*

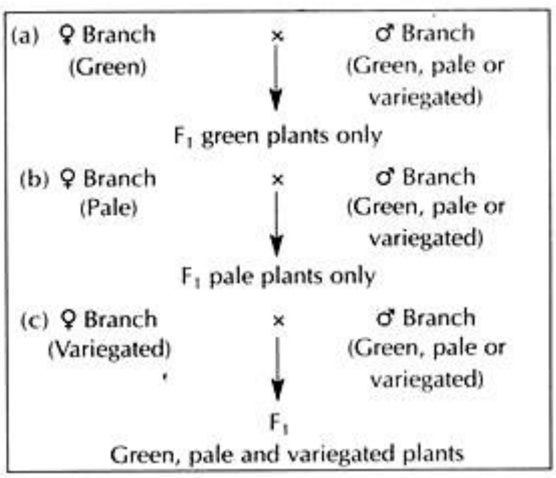
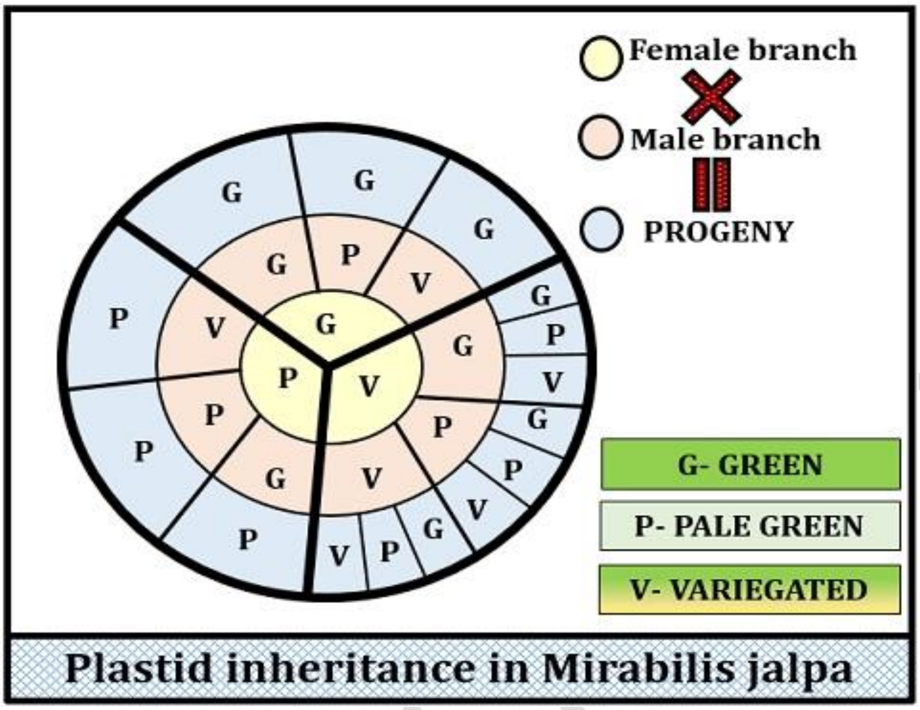


Figure:Plastid inheritance in Mirabilis jalapa showing dependence on the nature of female branch

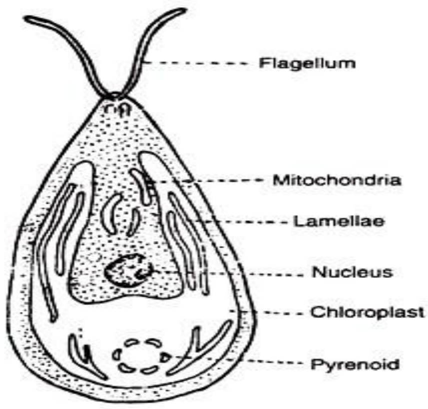
In all these cases Fi resembles with mother.This can also shown by clock representation:



From this clockwise representation we can understand that the colour of progeny branches are decided by the plastid present in cytoplasm showing cytoplasmic inheritance.

2.Chloroplast genetics in *Chlamydomonas:*

The **chloroplast genome** in Chlamydomonas is a circular **DNA** containing some number of genes necessary for functioning of the **chloroplasts** and maintaining their structure. These **DNA** also contain the genes of ribosomal and transfer RNA.



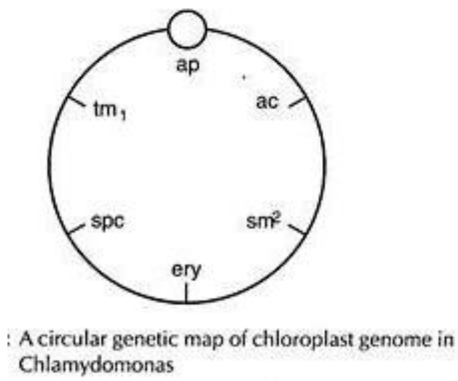


Figure:The green alga *Chlamydomonas*

figure: Circular chloroplast genome in *Chlamydomonas*

Ruthsagar (1965) has reported some cases of extrachromosomal inheritance in green alga ***Chlamydomonas reinhardi.*** It does not have different sexes but has positive and negative strains or mating types (mt^+ and mt).

The sexual reproduction involves fusion between two morphologically similar but physiologically dissimilar gametes of two different mating types (+ strain or mt^+ and – strain or mt^-) and the gametic fusion results in zygote.

Ruthsagar (1965) isolated two strains of Chlamydomonas: one strain was resistant (Sm^r) to 500 jig of streptomycin per ml. of culture solution and the other was sensitive (Sm^s).

When the reciprocal crosses were made between the streptomycin resistant (Sm^r) and streptomycin sensitive (Sm^s) strains, the following results were obtained:

$Sm^r\ mt^+$ ♀ × $Sm^s\ mt^-$ ♂	$Sm^s\ mt^+$ ♀ × $Sm^r\ mt^-$ ♂
↓	↓
All Sm^r (F_1 Hybrids)	All Sm^s (F_1 Hybrids)

The diploid cells undergo meiosis and give rise to four haploid cells (tetrads) as shown in figure.

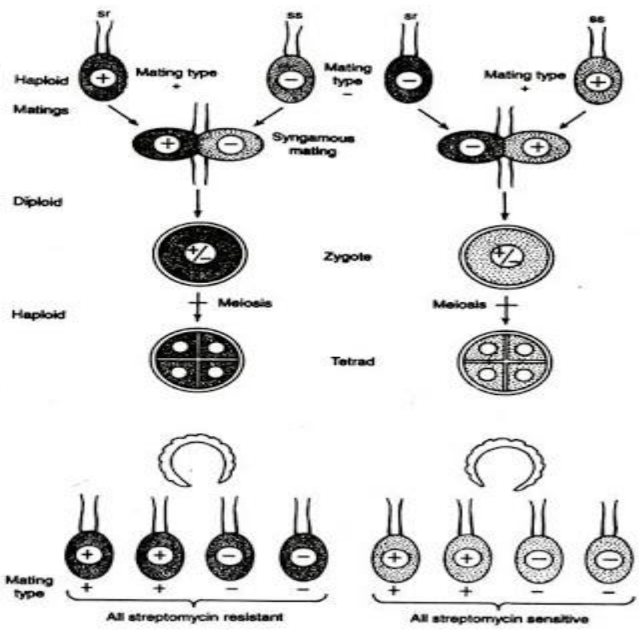


Figure: Uniparental inheritance in *Chlamydomonas*

Using the analogy of higher organisms, mt^+ is referred to as female and mt^- as male. The mating type genes mt^+ and mt^- segregate in 1: 1 ratio as expected for the Mendelian inheritance. In the higher organisms formation of zygote involves fusion between an egg and a sperm and the contribution of cytoplasm to the zygote by sperm is negligible.

Under such condition it is easy to comprehend the mechanism of maternal inheritance.

But in Chlamydomonas, male (mt^-) and female (mt^+) gametes being indentical in size contribute equal amount of cytoplasm to the zygote, even then the cytoplasmic features of only mt^+ strain is expressed in F_1, i.e., it is uniparental inheritance. Now the question arises, what happens to the cytoplasmic determinants of mt^- gametes?

This problem was solved by Ruthsagar who discovered that the chloroplast DNA of mt^- strain becomes degraded in zygote and the mt^+ gene or a gene closely associated to it specifies a restriction-modification system. Here restriction implies degradation and the modification means protection.

The system encoding the DNA modifying enzyme, modifies its own DNA which cannot be degraded by the restriction system. The mt^+chloroplast DNA which is not modified or protected is degraded by restriction system of mt^+ gamete.

3. Petites in Yeast:

Mitochondria are the cytoplasmic organelles which contain its own DNA and various respiratory enzymes and are main source of energy for the cell.The complexity of structure of the mitochondria and their similarity in some ways to plastids suggest the possibility that they may be inherited in the same way as the plastids.

The fact that mitochondrion contains its own DNA has led some to speculate that it evolved from symbiotic micro-organism that gradually lost the ability to exist independently. There is enough evidence in support of this. But, some people disagree with this. Mitochondria cannot be regarded truly autonomous cytoplasmic organelles as they require both their own genes and nuclear genes in order to exist.

The mitochondrial heredity has been exemplified by yeast *(Saccharomyces cereviceae):*

Certain strains of yeast (*S. cereviceae*) produce tiny colonies when grown on agar medium. Ephrussi (1953) observed that one or two out of every one thousand colonies were only about one-third or one- half of the diameter of the remainder. The small colonies are termed as petite colonies.

Cells from the normal large colonies, when spread on culture medium, further produced a small proportion of petite colonies and this happened so time after time. The cells from the small colonies were true breeding and they produced only petites.

Biochemical studies have established that the slow growth of petite colonies was due to the loss of aerobic respiratory enzymes particularly cytochrome a and b and enzyme cytochrome oxidase occurring in mitochondria of the cells and the utilization of the less efficient fermentation process by the cells.

The petite phenotype can result either from mutation of nuclear genes or from mitochondrial genes. Petite mutants resulted due to mutation in a nuclear gene follow Mendelian pattern of inheritance with segregation occurring in heterozygotes.

This type of petite mutation is called segregational petite or nuclear petite. When the individuals of petite colony are crossed to the individuals from normal large sized colony, normal zygotes are formed which produce normal cells vegetatively.

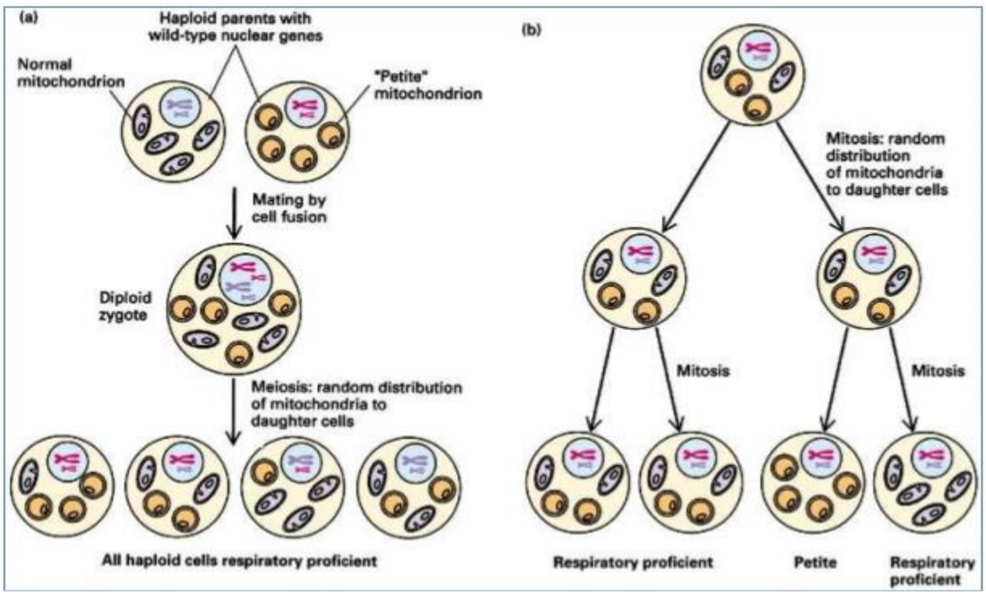


Figure: Mitochondrial inheritance in Yeast

4.Kappa particle in Paramecium:

- Paramecium having kappa particle: Killer strain
- Paramecium having no kappa particle: Sensitive stain

The inheritance of kappa particle is explained by Sonneboan. Kappa particle is responsible for production of a toxic substance known as **paramecin** which kills those paramecia having no kappa.
The production of kappa is dependent upon dominant gene **'K'** present inside the nucleus.

Paramecium

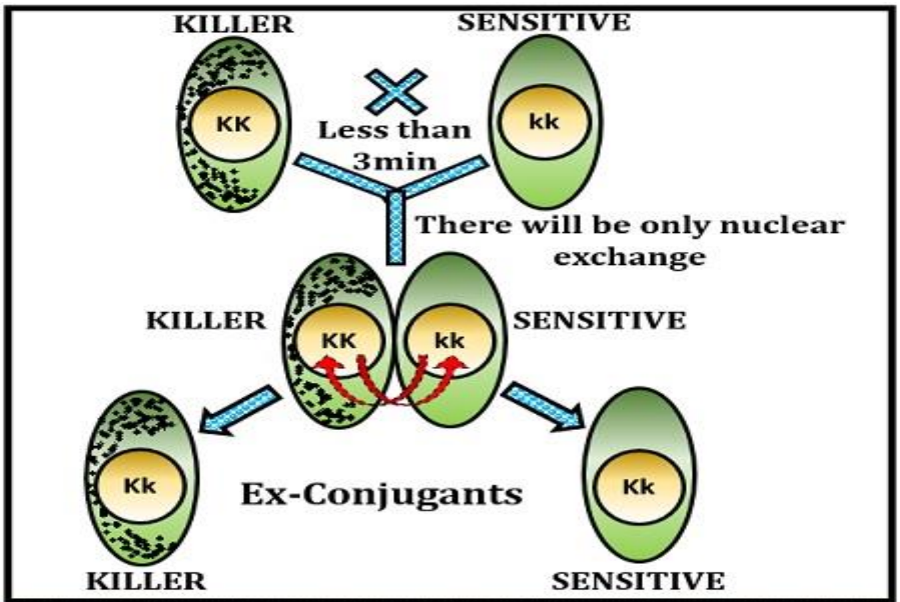
Killer strain — (K gene and kappa particle)

Sensitive strain — (kk + no kappa)

To understand the concept of kappa particle inheritance, let us cross a pure killer and sensitive strain. The pure killer strain will have both dominant genes i.e. KK plus a protein factor Paramycin. The pure sensitive strain will only have the recessive gene. During crossing over, there will be **conjugation** between KK gene with kk gene. If the duration of conjugation is **less than 3 minutes**, then there will be an only **nuclear exchange**.

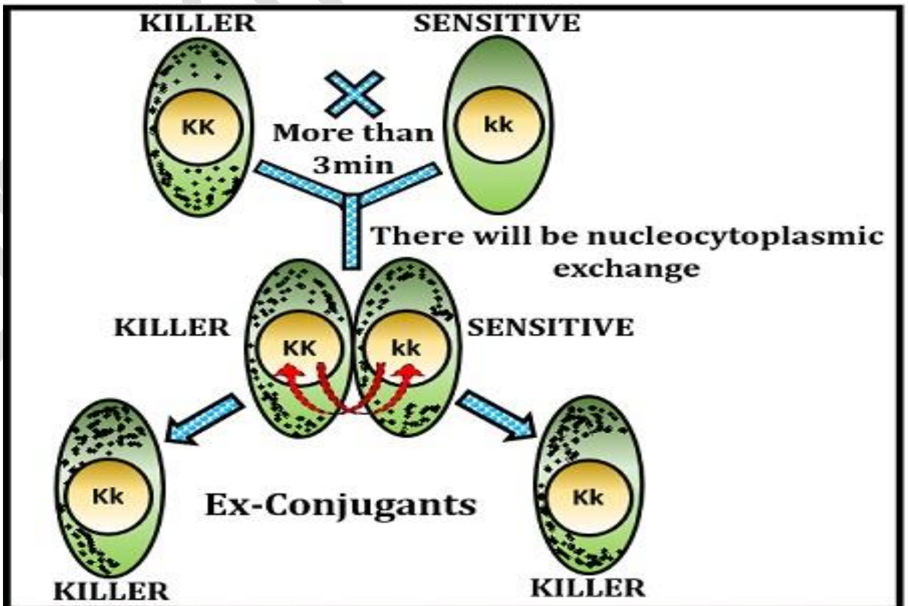
Therefore at the time of crossing over, one dominant and one recessive gene will exchange between the killer and sensitive strains. After crossing over, two offspring will produce refer as "**Ex-conjugants**".

One **kille**r strain (Kk) and one **sensitive** strain (Kk) will produce as a result of this type of crossing over. The ex-conjugant Kk will behave like a killer strain because it is having both dominant gene 'K' and kappa particles as there is only nuclear exchange.



Nuclear inheritance in Paramecium

Now, let us understand the concept of nucleoplasmic inheritance by the same crossing over. As there will be conjugation between KK gene with kk gene. If the duration of conjugation is **more than 3 minutes**, then there will be nuclear exchange along with Cytoplasmic exchange. Therefore at the time of crossing over, one dominant and one recessive gene will exchange along with cytoplasmic exchange. Therefore, this type of inheritance will refer to as "**Nucleoplasmic inheritance**". After crossing over, two offspring will produce refer as "Ex-conjugants". **Both killer** strain will produce as a result of this type of crossing over.



Nucleocytoplasmic inheritance in Paramecium

5.Shell coiling in snails (Limnaea peregra):

One of the classical examples of intricate relationship between maternal genotype and egg cytoplasm **"phenotype"** was studied in snails by Sturtevant. He showed that there are two strains of water snails that differ each other in the direction of coiling of shell.

Looking into the opening of the shell it shows two types of coiling:

- one strain the shell always coils to the left (sinistral)
- the other strain the shell always coils to the right (dextral).

Figure: Shell coiling in snails.

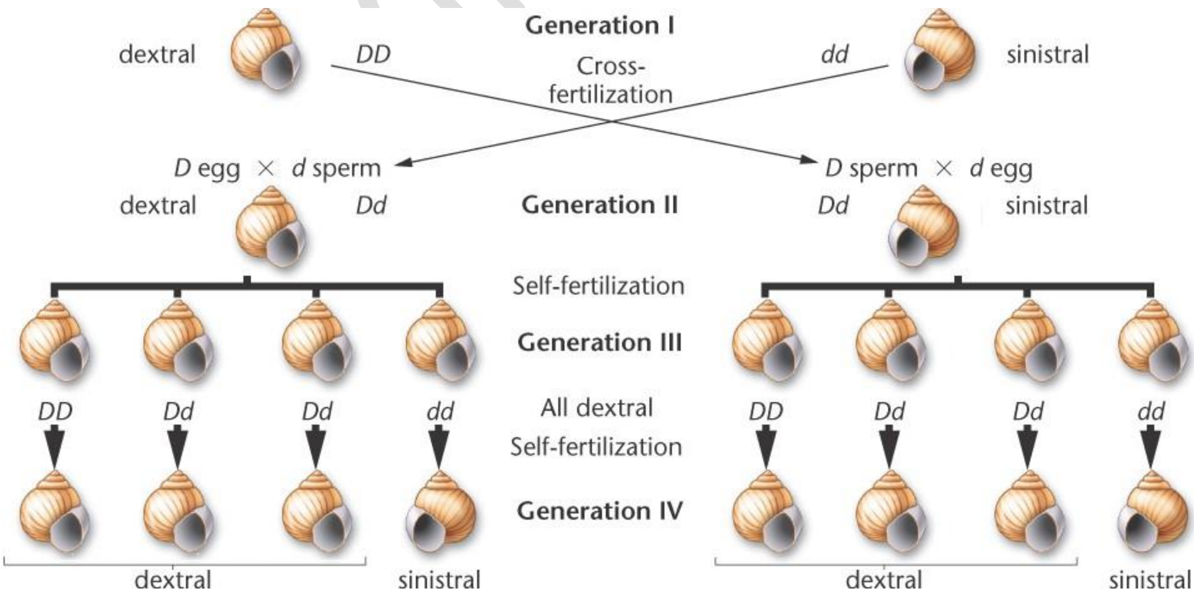


Figure: Maternal effect in the direction of coiling of the shell in snails

In the cross dextral (female) x sinistral (male) all the F, progeny have dextral coils implying that dextral is dominant over sinistral. However, in the F_1, x F_1, cross (i.e., inbreeding), all the F_1 snails are also dextral. The reciprocal cross dextral (male) x sinistral(female) produces F_1, progeny that are all left coiler. In this case F_1, x F_1, cross also yields only dextral coils.

From these experiments it becomes clear that coiling of snails is not determined by individuals' own genes but by those of mother.

The offsprings whose mothers are either homozygous or heterozygous for right coiling are right coilers even if they are homozygous for sinistrality (left coiling). In the same way offspring of left coiling mother are left coilers even if they carry dominant genes for right coiling.

The F_2 females of either cross (right coiler) when mated with males of any genotype produce at an average right coilers and left coilers in 3: 1 ratio. But 3: 1 ratio appears in F_3 and not in F_2. If F_2 males are mated with homozygous right coiling females, there is no segregation and all their progenies are right coilers, but if they are mated with homozygous left coiling female's only left coilers are produced.

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