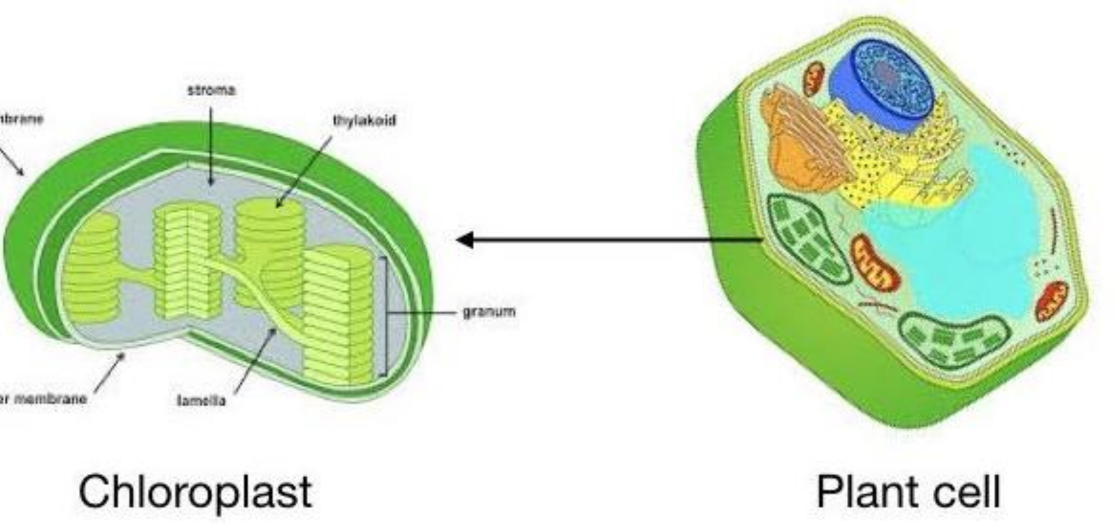
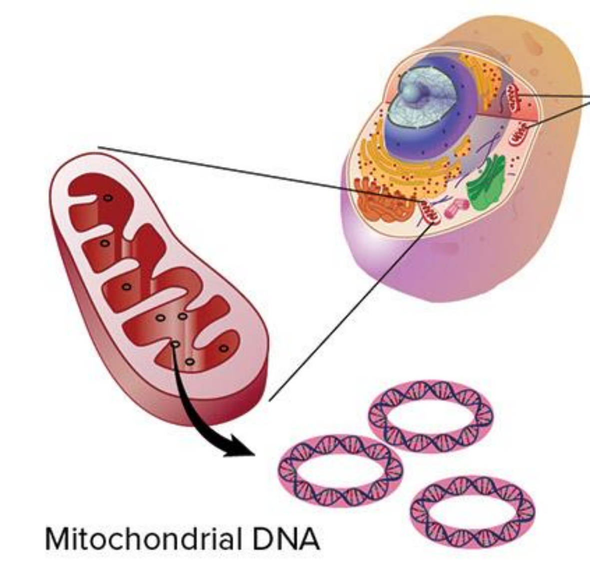




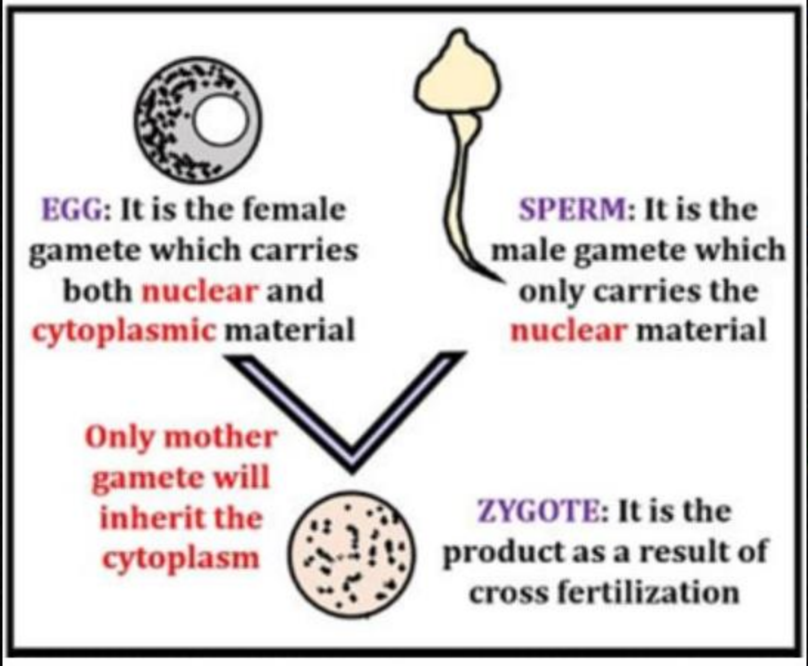
Extra Chromosomal Inheritance

Content

- What is Extrachromosomal inheritance?
- Chloroplast inheritance
  - Variegation in Four o'clock plant
  - Chloroplast segregation in Chlamydomonas
- Mitochondrial inheritance
  - Pokyness in Neurospora
  - Cytoplasmic male sterility
- Maternal effects
- Summary

Extrachromosomal Inheritance

- Extranuclear inheritance is defined as non-mendelian inheritance, which occurs when phenotype result from genetic influence other than the genes located on chromosomes in the nucleus
- Mitochondrial and chloroplasts are organelles that carry their own DNA and have a tendency to inherit this extra chromosomal DNA
- The genes in mitochondrial and chloroplast genomes are known as extranuclear genes, extrachromosomal genes, cytoplasmic genes, non-mendelian genes or organellar genes.

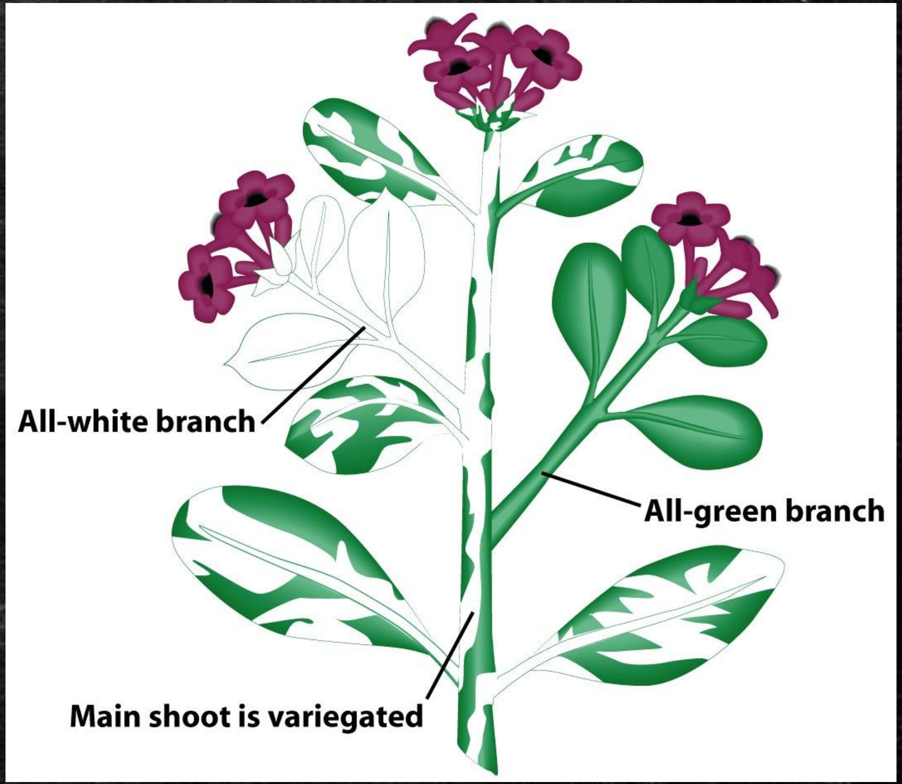


- Mitochondrial and chloroplast genes usually show uni parental inheritance from generation to generation.
- In uniparental inheritance, all progeny (both males and females) have the phenotype of only one parent.
- Usually for multicellular eukaryotes, the phenotype of the mother is inherited exclusively a phenomenon called maternal inheritance.
- Maternal inheritance occurs because the amount of cytoplasm in the female gamete usually greatly exceeds that in the male gamete.
- Therefore, the zygote receives most of its cytoplasm (containing the extranuclear genomes of the mitochondria and, where applicable, of the chloroplasts) from the female parent and a negligible amount from the male parent.

Variegation in Four o’clock plant

- Variants of *Mirabilis jalapa* in which some branches had white leaves, some had green leaves and some had variegated leaves

Crosses between three leaf colours: Female		Male	Expression of leaf colour in F_1
Green	×	Green	Green
	×	White	Green
	×	Variegated	Green
White	×	Green	White
	×	White	White
	×	Variegated	White
Variegated	×	Green	Green, white and variegated in various ratios in each cross
	×	White	
	×	Variegated	



Variegation in Four o’clock plant

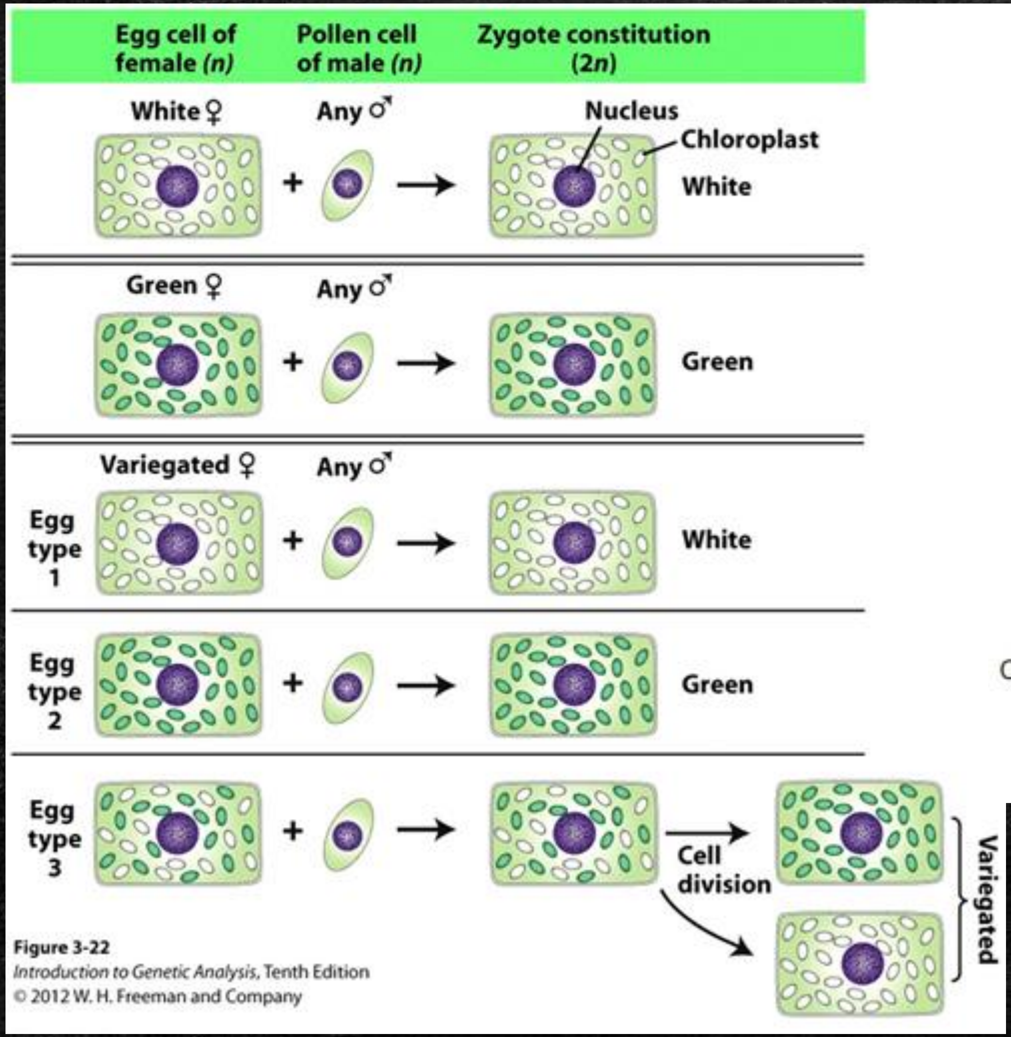
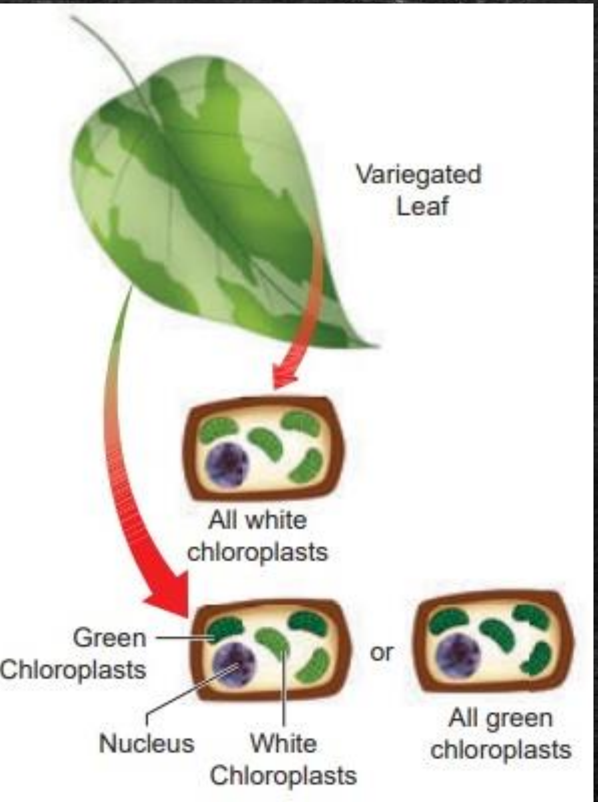


Figure 3-22
Introduction to Genetic Analysis, Tenth Edition

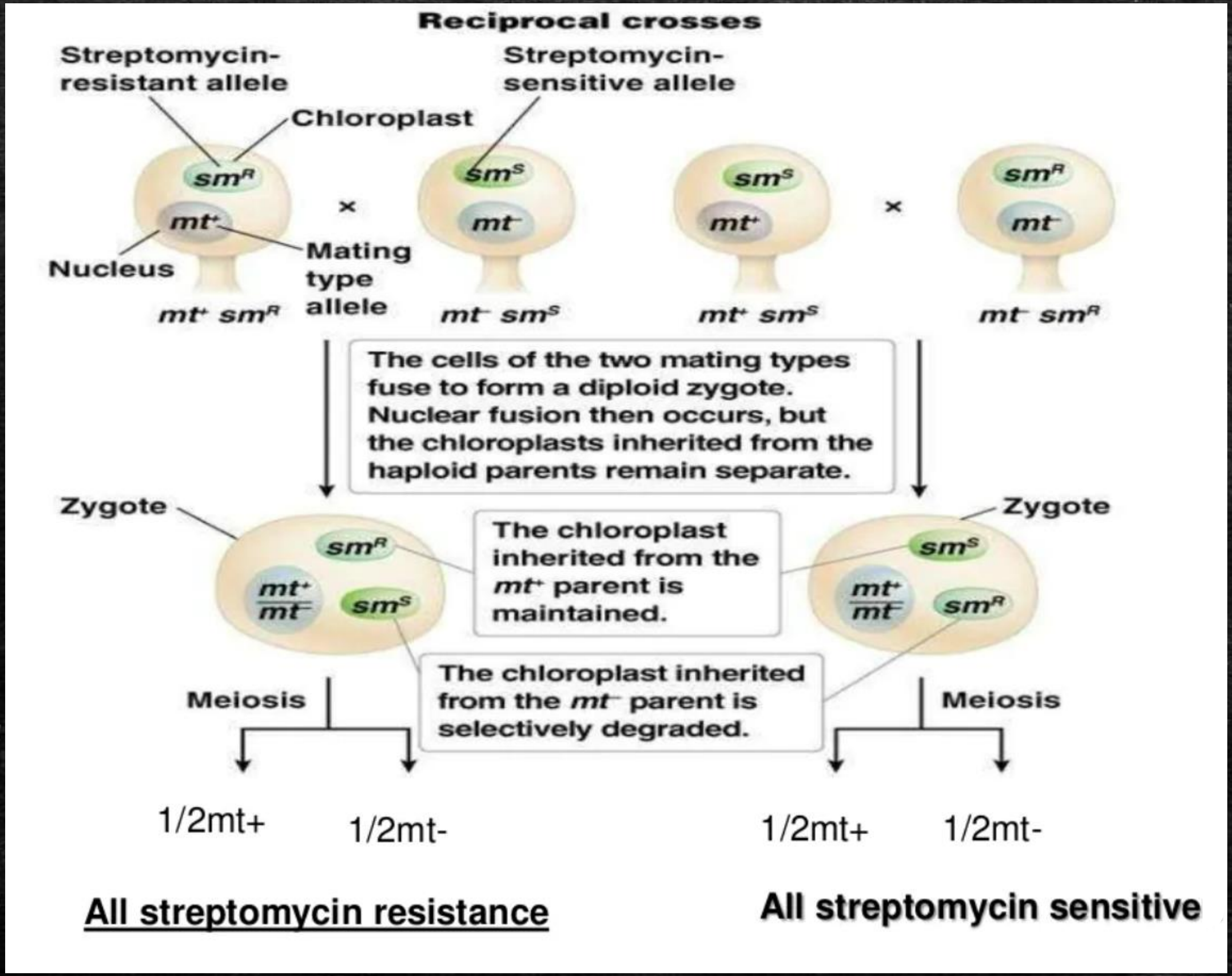


- In this example, maternal inheritance occurs because the chloroplasts are transmitted only through the cytoplasm of the egg
- The pollen grains do not transmit chloroplasts to the offspring

Chloroplast segregation in Chlamydomonas

- Chlamydomonas is a single celled haploid green algae with a single chloroplast containing 50 to 100 genes
- It has two mating type mt(+) and mt(-) which can fuse to form a diploid zygote

Chloroplast segregation in Chlamydomonas



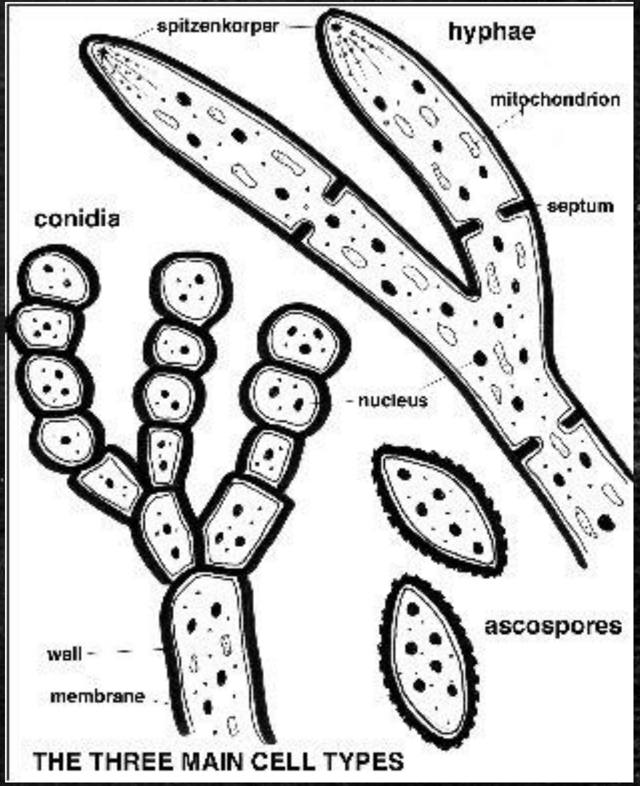
Pokyness in Neurospora

- In 1952, Mary Mitchell isolated a mutant strain of Neurospora that she called poky
- Poky: A mutation of Neurospora that produces a petite-like phenotype
- Poky Neurospora is:

➢ Slow growing

➢ It shows maternal inheritance

➢ It has abnormal amount of cytochromes



Pokyness in Neurospora

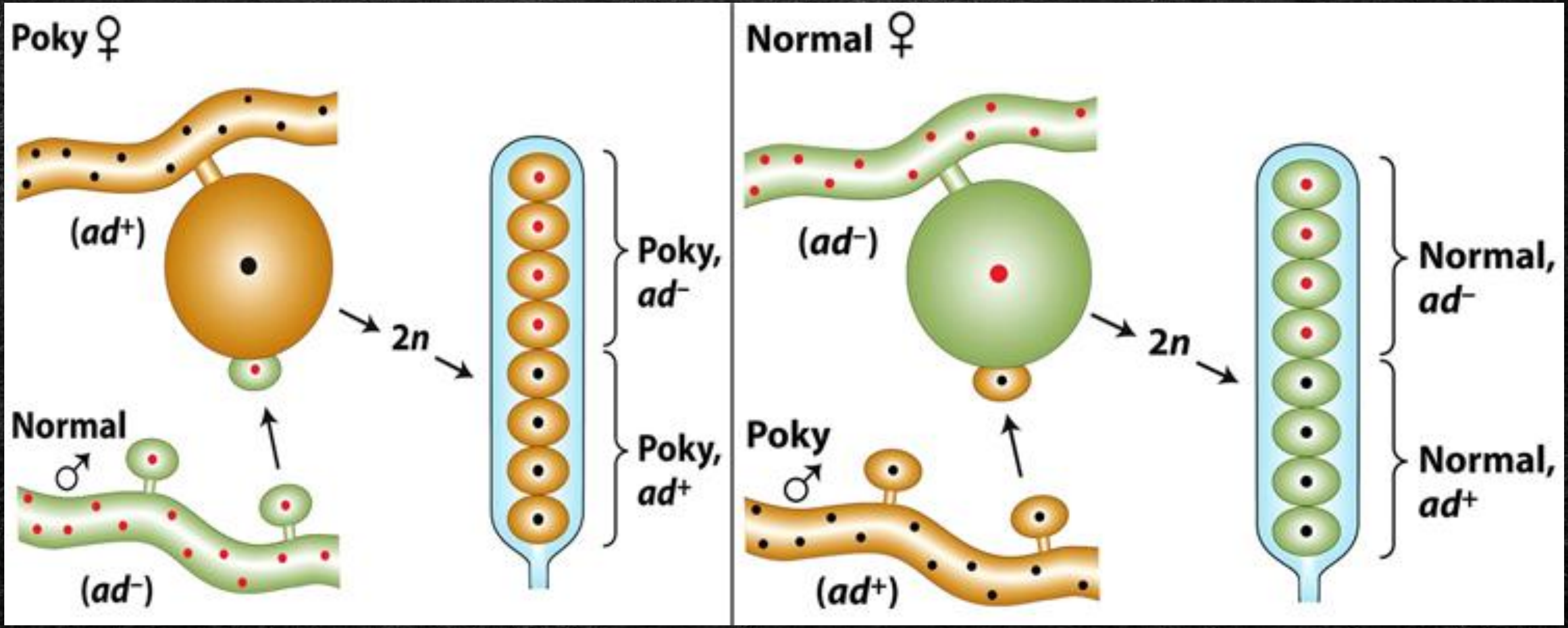
- It is possible to cross some fungi in such a way that one parent contributes the bulk of cytoplasm to the progeny and this cytoplasmic contributing parent is called female even though no true sex is involved

- Maternal inheritance for the poky phenotype was established in the following crosses:

  - **Poky (female) x Wild type (male) → all poky**
  - **Wild type (female) x Poky (male) → all wild type**

- Poky Neurospora possess altered mtDNA cytochromes, leading to less ATP synthesis, thereby causing slow growth

Pokyness in Neurospora



Question 1

115. In *Neurospora*, the mutant *stp* exhibits erratic stop-and-start growth. When a female of *stp* strain is crossed with a normal strain acting as a male, all progeny individuals showed *stp* mutant phenotype. However, the reciprocal cross resulted in all normal progeny individuals. These results can be explained on the basis of

A. maternal inheritance
B. sex limited inheritance
C. sex influenced inheritance
D. *stp* mutation may be located in mitochondrial DNA

The most appropriate statement or combination of the above statements for explaining the experimental results is :

1.	A and C	2.	C only
3.	A and D	4.	B and D

Question 2

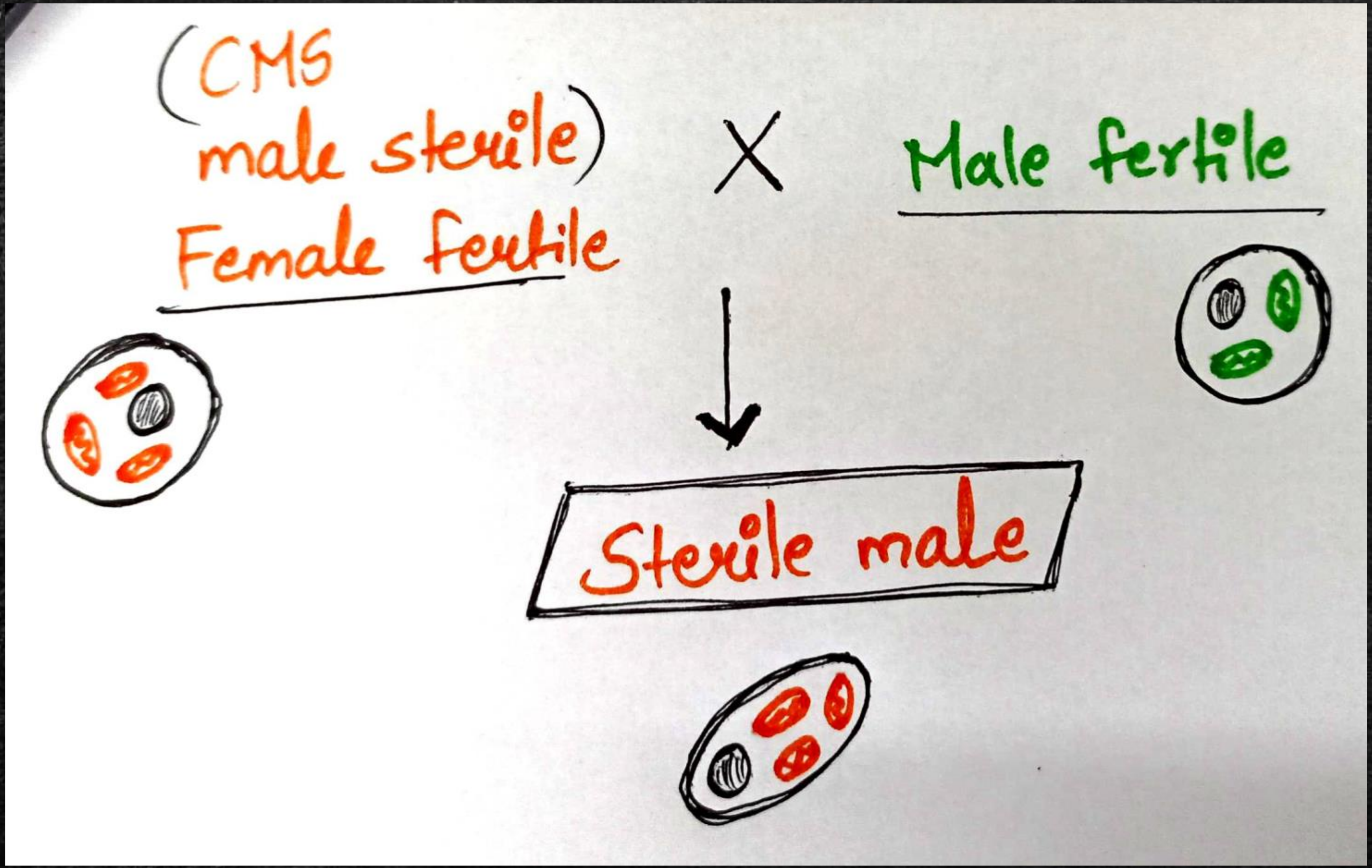
- A neurospora stp strain have start and stop growth behaviour. The mutated gene was found to be on mitochondria. If male Neurospora have stp mutation is crossed with wild type female Neurospora . Phenotype of progenies will be.

1. All start and stop mutant
2. All wild type
3. Majority of start and stop mutant
4. Majority of wild type.

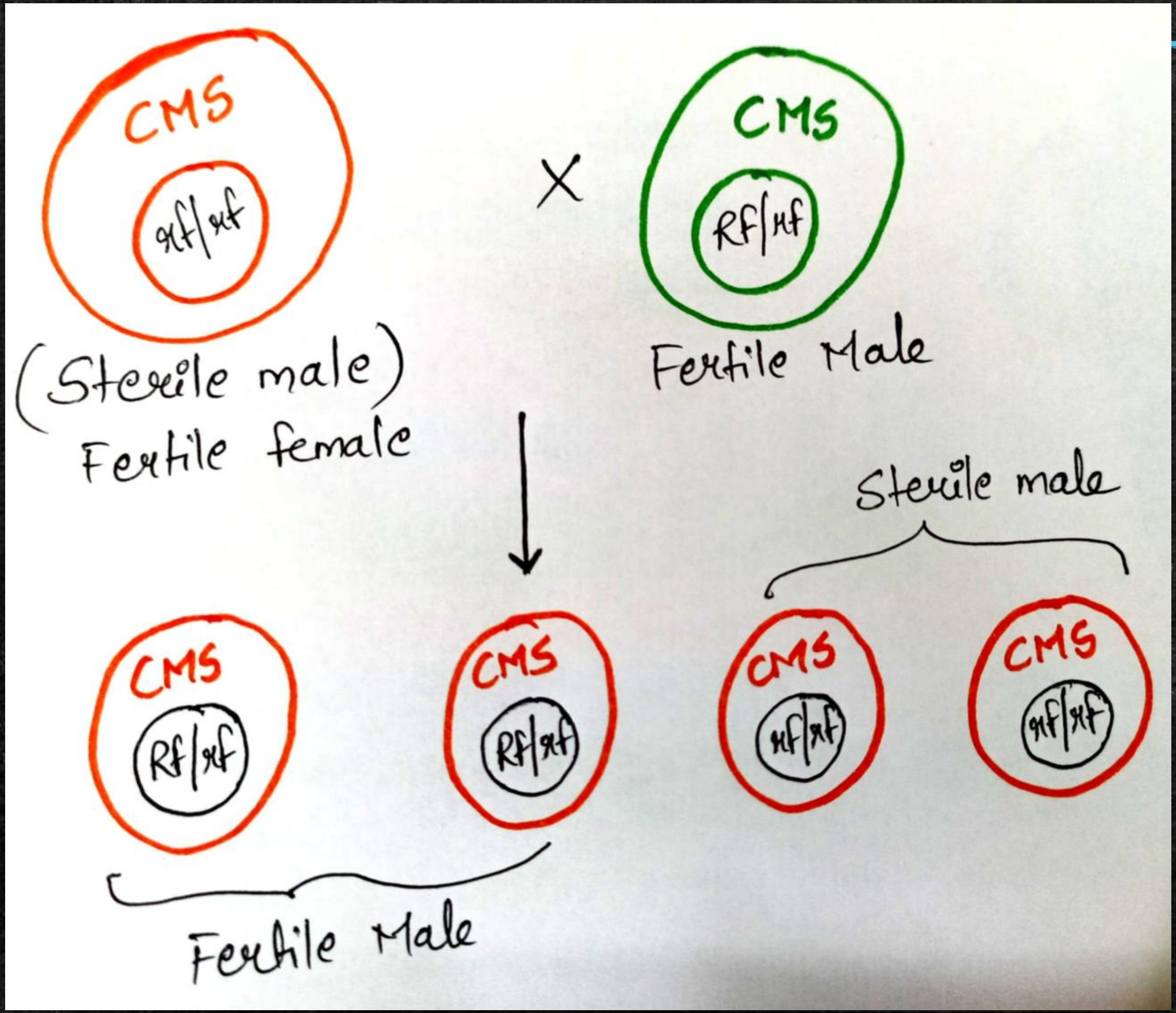
CYTOPLASMIC MALE STERILITY (CMS)

- CMS is a condition in which a corn plant does not produce a functional pollen, but the female reproduction organs and fertility are normal
- Corn Plant: both male and female part are present together in one plant
- Male sterility may result from mutations of nuclear genes or extranuclear genes, producing genic male sterility and cytoplasmic male sterility (CMS) respectively
- The mutation in CMS is in the mitochondrial genome.

CMS (Mitochondrial gene mutation)



Restorer of Fertility (Nuclear gene mutation)



- Restorer of fertility (Rf) is a gene present on the nucleus, responsible for the fertility of the male
- Rf is dominant and overrides CMS, rf is recessive and cannot override CMS

Cytoplasmic inheritance in humans

- **Leber's hereditary optic neuropathy**
- Mutation in ETC proteins, CO and ATPase
- Results partial or complete blindness from optic nerve degradation
- caused by a homoplasmic missense mutation in the ND4 gene

- **Kearns-Sayre syndrome.**
- Neuromuscular defects.
- Due to large deletions in mtDNA
- Accumulation of pigments in retina
- caused by a heteroplasmic mtDNA deletions

- **(MERRF)**
- myoclonic epilepsy and ragged red fiber disease
- caused by a heteroplasmic mutation in the tRNA gene

Exception to maternal inheritance

- **Heteroplasmy –**
- Inheritance of mitochondrial DNA/ Cp DNA from both parents
- Biparental plants - Oenothera
- Biparental animals - Mytilus

- **In heteroplasmy there is a likelihood of genetic recombination between maternally derived and paternally derived mtDNA molecules. Such recombination will lead to significant diversity of mtDNA in an individual**

Question 3

2. Cytoplasmic male sterility (CMS) in plants is caused by mutation in the mitochondrial genome. CMS can be restored by a nuclear gene, restorer of fertility (Rf), which is a dominant character. If a male sterile pea plant is pollinated by a fertile male pea plant with Rf in heterozygous condition, the progeny obtained will have

a) All male sterile progeny.
b) All fertile progeny.
c) 50% of the progeny fertile and 50% male sterile.
d) 75% of the progeny fertile and 25% male sterile.

CSIR NET 2020

Maternal Inheritance Vs Maternal Effect

Maternal Inheritance

- Those phenotypes controlled by organelle genes exhibit maternal inheritance

Maternal Effect

- Those phenotypes that are controlled by nuclear factors found in the cytoplasm of the female are said to express a maternal effect

Maternal Effect

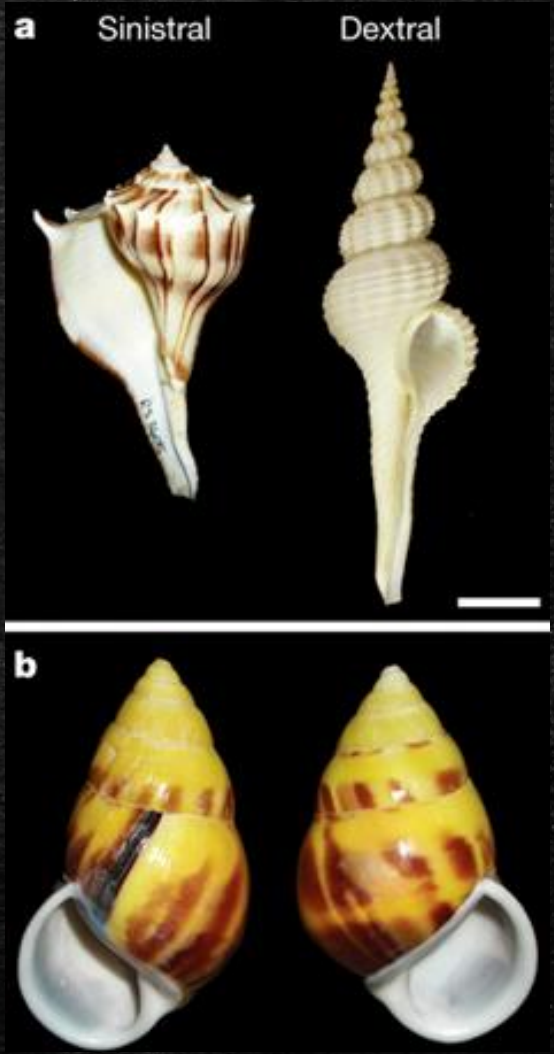
- A maternal effect is a situation where the phenotype of an organism is determined by genotype of its mother
- Maternal effect describes the influence on an early embryo's development exerted by substances (e.g., mRNA, transcription factors) found in the ovum before it is even a zygote (before fertilization)
- Eg: Shell coiling in snails

Shell coiling in snail (lymnaea)

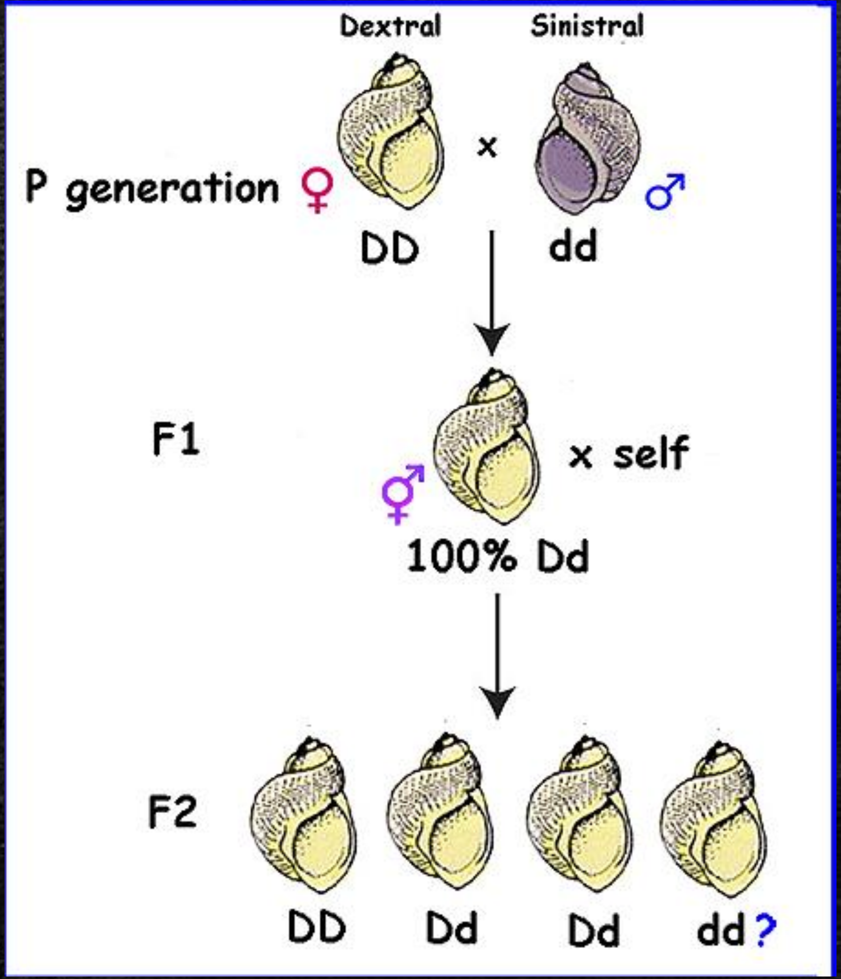
- In these little freshwater snails, there are two directions the shell can coil:

➢ **dextral** (right-handed) is the more common coiling direction

➢ **sinistral** (left-handed) is the rarer direction



Let's mate some snails…



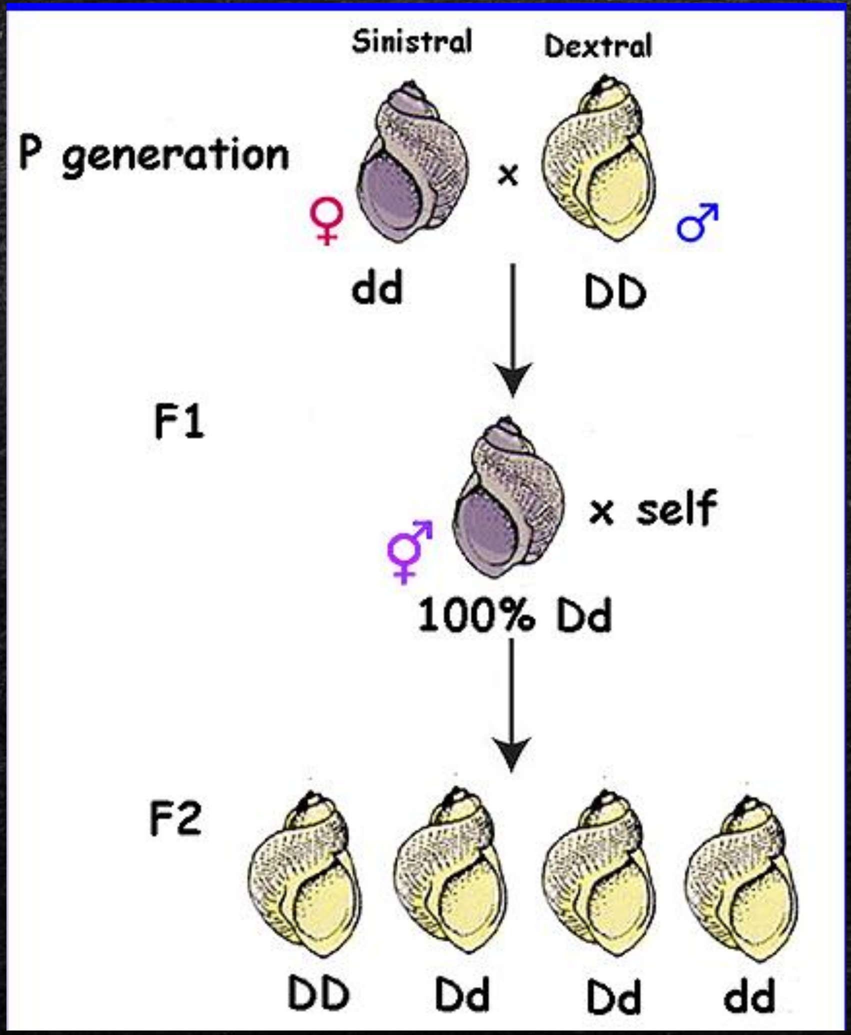
female dextral x male sinistral yields 100% dextral F1

- This would suggest that dextral (D) is dominant to sinistral (d)

- If so, what is the expected ratio for the F2 of a Dd x Dd cross?

- The actual result:
- F1 x F1 yields 100% dextral in F2

Let's mate some snails…



- male dextral x female sinistral yields 100% *sinistral* F1

- F1 selfing of this progeny yields…100% dextral!

Why does this happen?

- Spiral cleavage direction is due to the tilt of the mitotic spindle (right or left) with respect to the direction of the embryo's animal/vegetal axis.
- The tilt direction is governed by the mother's cytoplasm, which is, in turn, controlled by her nuclear DNA.
- The ovum contains maternal cytoplasm. Hence, the direction of the baby snail's shell coiling is determined, not by its own genes, but by the mitotic spindle of it's mother's cytoplasmic legacy.
- Here are all the possibilities:
- No matter which direction her own shell coils, a **DD or Dd** mother snail will always produce right-tilting ova. All her babies will be **dextral**.
- No matter which direction her own shell coils, a **dd** mother snail will always produce left-tilting ova. All her babies will be **sinistral**.

Question 4

- A male snail homozygous for dextral alleles is crossed with a female homozygous for sinistral alleles. All the F1 individuals showed sinistral phenotype. When F1 progeny snails were self fertilized all individuals of F2 progeny had dextral coiling. This experiment demonstrated.

1. Dominant epistasis as dextral allele is dominant over sinistral allele.
2. Recessive epistasis as in F2 dextral allele appeared in homozygous condition.
3. Maternal effect as the nuclear genotype of the F1 mother has governed the phenotype of the F2 individuals.
4. Maternal inheritance as the mitochondrial genes of the F1 mother has governed the phenotype of the F2 individuals.

Summary

- Extranuclear inheritance is defined as non-mendelian inheritance, which occurs when phenotype result from genetic influence other than the genes located on chromosomes in the nucleus
- Variegation in Four o'clock plant- chloroplast inheritance
- Chloroplast segregation in Chlamydomonas- the chloroplast inherited from the mt(+) type parent is maintained
- Pokyness in Neurospora, CMS- mitochondrial inheritance
- Male sterility may result from mutations of nuclear genes (Rf) or extranuclear genes, producing genic male sterility and cytoplasmic male sterility (CMS) respectively
- Maternal effect is a situation where the phenotype of an organism is determined by genotype of its mother

Thank you!