



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Lecture – 14

Cytoplasmic Inheritance

by

Dr. Praveen Kumar

*Asst. Prof. **GPB***

MSSSoA, CUTM, Odisha



Historical

- ❖ First evidence of cytoplasmic inheritance was presented by Correns in *M. jalapa* and by Baur in *Pelargonium zonale* in 1908.
- ❖ In 1924 Jenkins described the iojap leaf variegation in maize, later studied in detail by Rhoades.
- ❖ Rhoades (1933) described CMS in maize.
- ❖ Sonnenborn (1943) discovered kappa particles in *Paramecium*, and described its cytoplasmic transmission.
- ❖ Presence of DNA in chloroplast first demonstrated by Ris and plaut (1962).
- ❖ Nass and coworkers (1963) proved the existence of DNA in mitochondria.
- ❖ Ruth Sager (1954) described cytoplasmic inheritance of streptomycin resistance in *Chlamydomonas*.

Cytosol, Plasmon, Plastom and Chondriom

- 
- Centurion
UNIVERSITY
Shaping Lives...
Empowering Futures
- ❖ 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 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**.



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, F_1 , F_2 , F_3 and subsequent generations do not show segregation for a cytoplasmically inherited trait, as F_1 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.

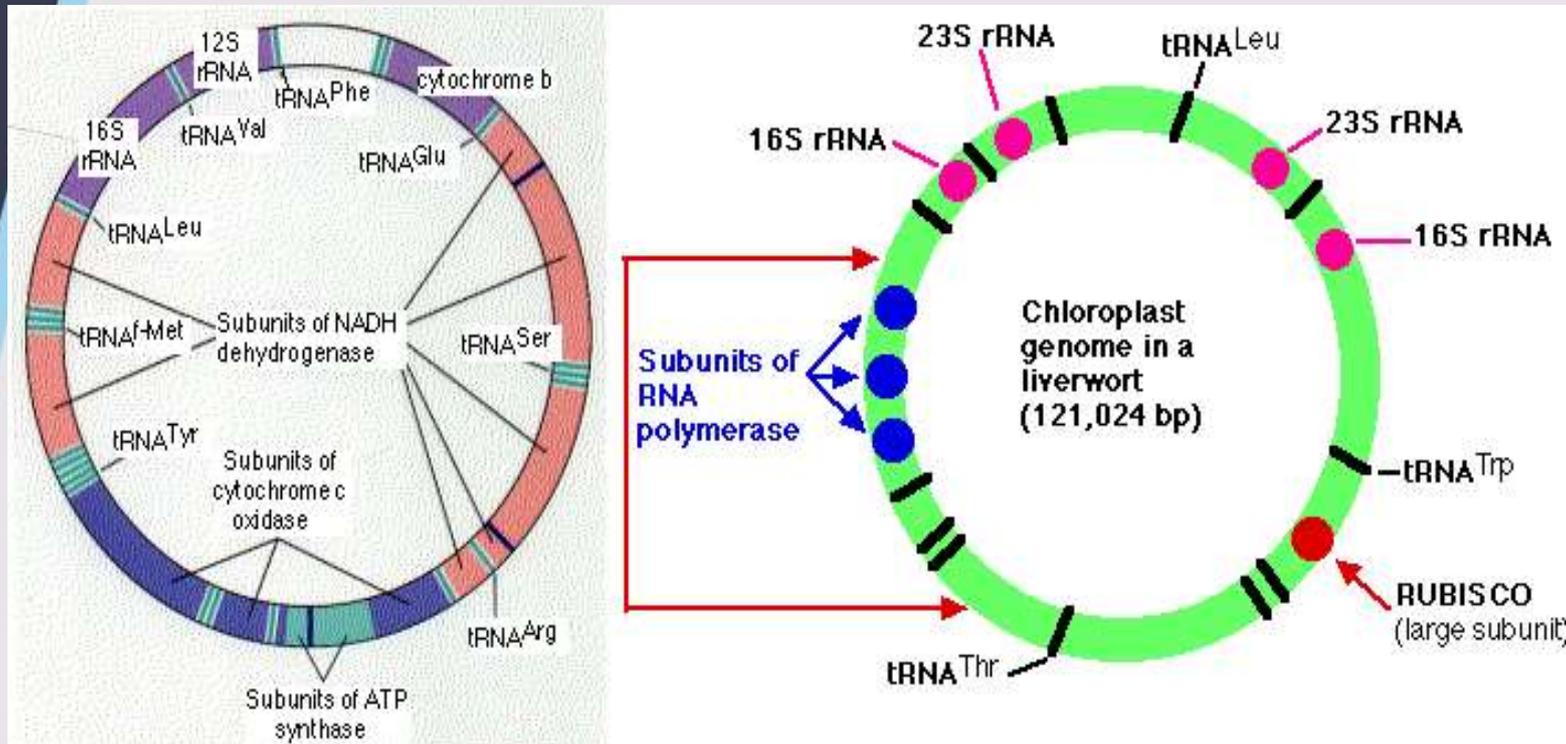
9. **Lack of association with a parasite or symbiont or virus:**

Only those cytoplasmically inherited traits which are not associated with parasites, symbionts or viruses can be regarded to be governed by plasmagenes.



1. Plastidial or chloroplast inheritance

- Plastids are 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 (cpDNA) in the stroma that is completely different from the nuclear genome.





Leaf variegation in *Mirabilis Jalapa*

- C. Corren 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.



Female Parent x Male Parent

Green x Green
x White Green
x Variegated

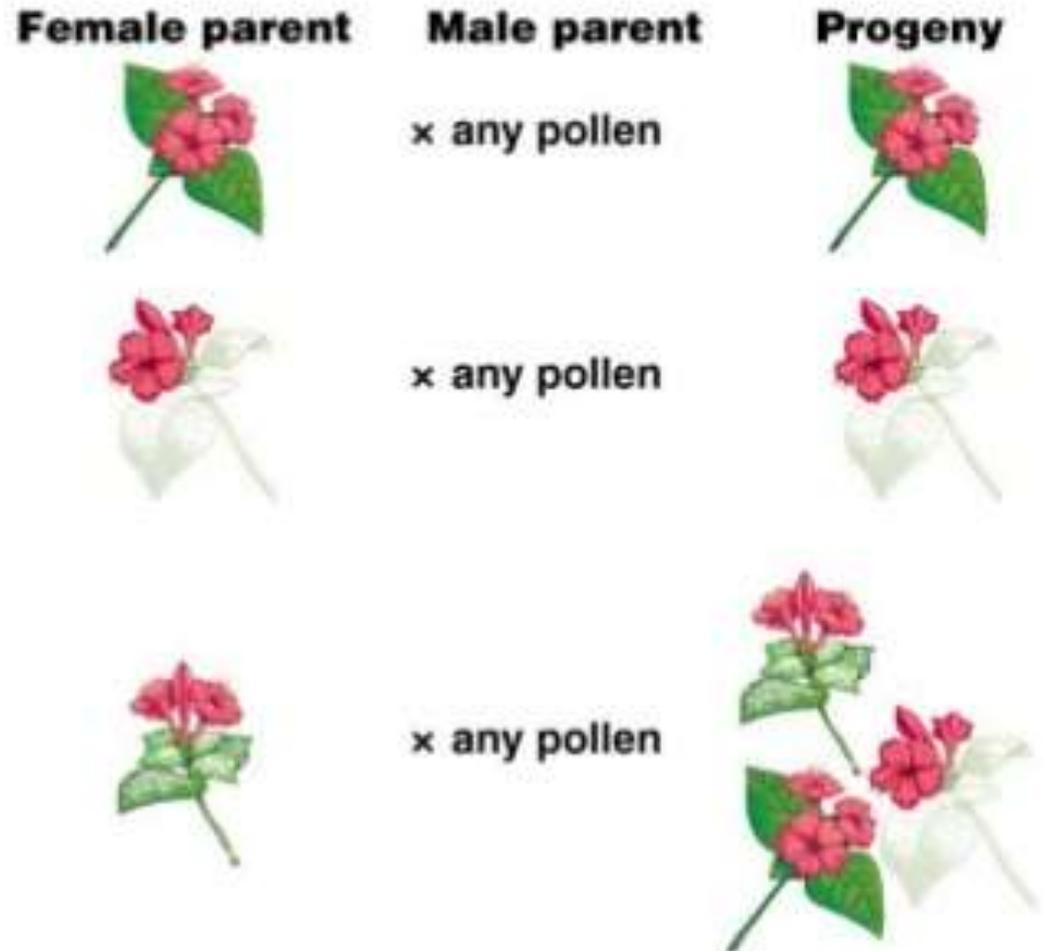
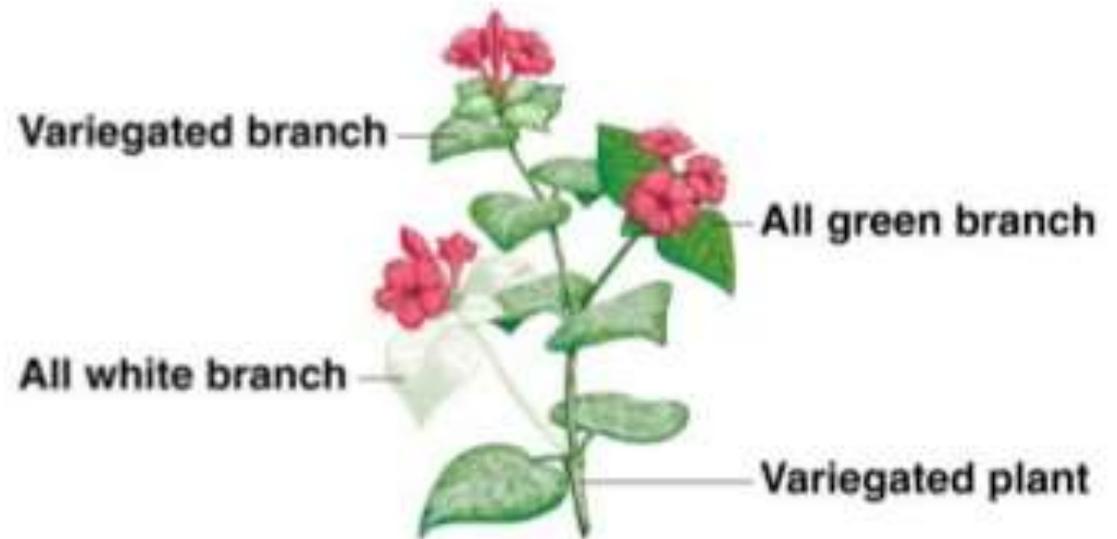
White x Green
x White Pale green
x Variegated

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



Results of Correns' Studies

- Correns made reciprocal crosses between flowers on branches with differently colored leaves
- The results of the tests showed that progeny invariably exhibited the same phenotype as the female parent in the cross
- This suggested that transmission of leaf color occurs by **maternal inheritance**, through genes transmitted in the ovule only





Centurion
UNIVERSITY
Shaping Lives...
Empowering Communities...

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



Centurion
UNIVERSITY
*Shaping Lives...
Empowering Communities...*

Parents

Female x Male

Phenotype

Green x lojap

Generation

F1
Green

Reciprocal Cross

Parents

Female x Male

Phenotype

ljop x Green

Generation

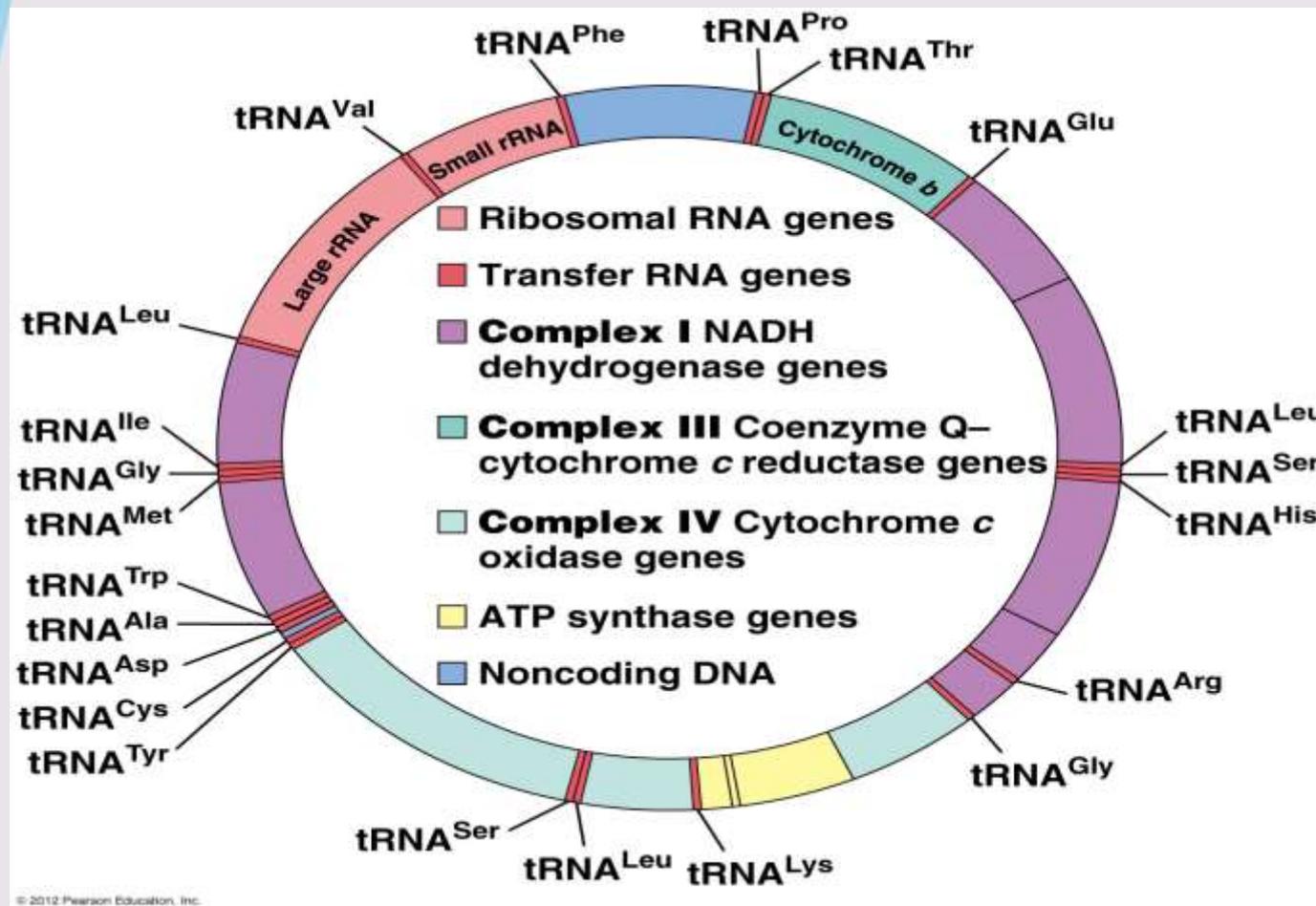
F1
Green, lojap, White in variable
proportion



Centurion
UNIVERSITY
Shaping Lives...
Empowering Communities...

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).



Cytoplasmic male sterility (CMS) in maize

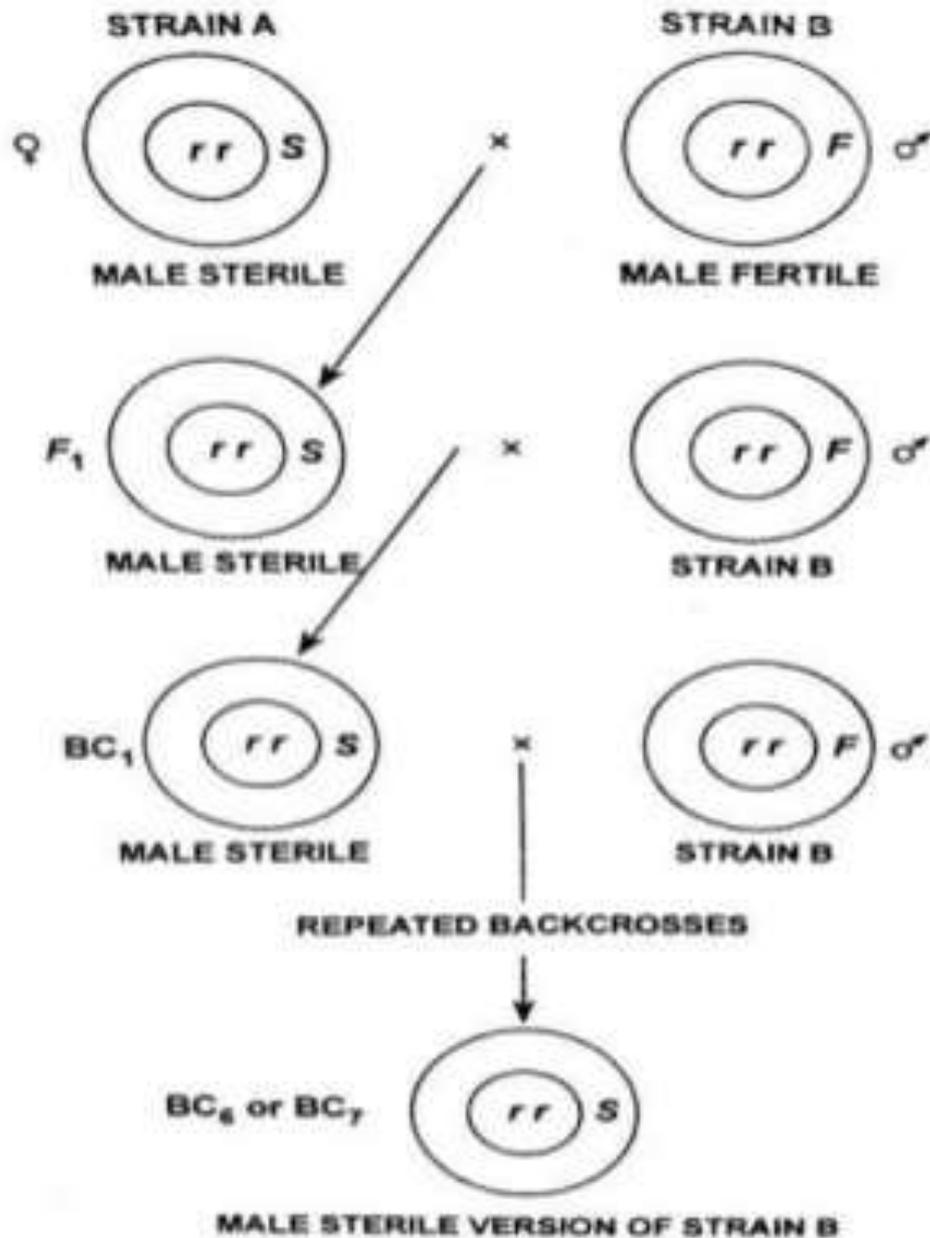


Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

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.



Cross the male fertile strain B (male parent) to a cytoplasmic male sterile strain A (used as female parent)

- (i) The F_1 would be male sterile
- (ii) 50% of the nuclear genes of F_1 would be from strain B
- (iii) Backcross the F_1 to strain B

- (i) 75% of the nuclear genes would be from strain B
- (ii) Backcross to strain B

- (i) This is the male sterile version of strain B (>99% of the nuclear genes from strain B)
- (ii) Maintained by crossing with male fertile strain 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

♀ x ♂
Poky x Wild



Poky

♀ x ♂
Wild x Poky



Wild

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



Centurion

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



S.N	Character	Chromosomal inheritance	Extra-chromosomal inheritance
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 their 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



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

THANK YOU