Cytoplasmic inheritance discovered in Paramecium and other ciliates

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Cytoplasmic inheritance discovered in Paramecium and other ciliates

Genome-wide DNA rearrangements

Mating type

Serotypes

Paramecium has a complex cellular biology

- *Eukaryotic*
- *Ciliates contain at least 2 nuclei*
  - *Germ-line micronucleus (MIC)*
  - *Somatic macronucleus (MAC)*
- *MAC is generated from the MIC*
- *Extensive genome rearrangements occur in the MAC*

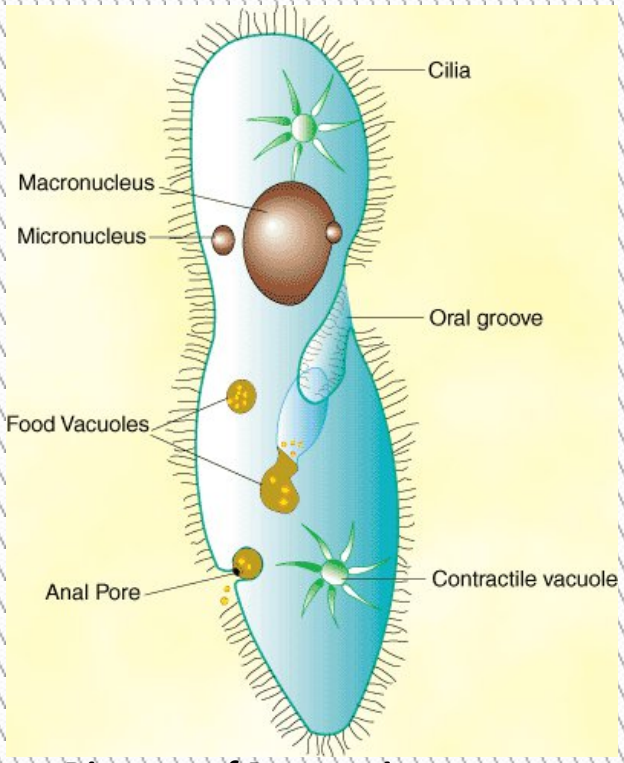
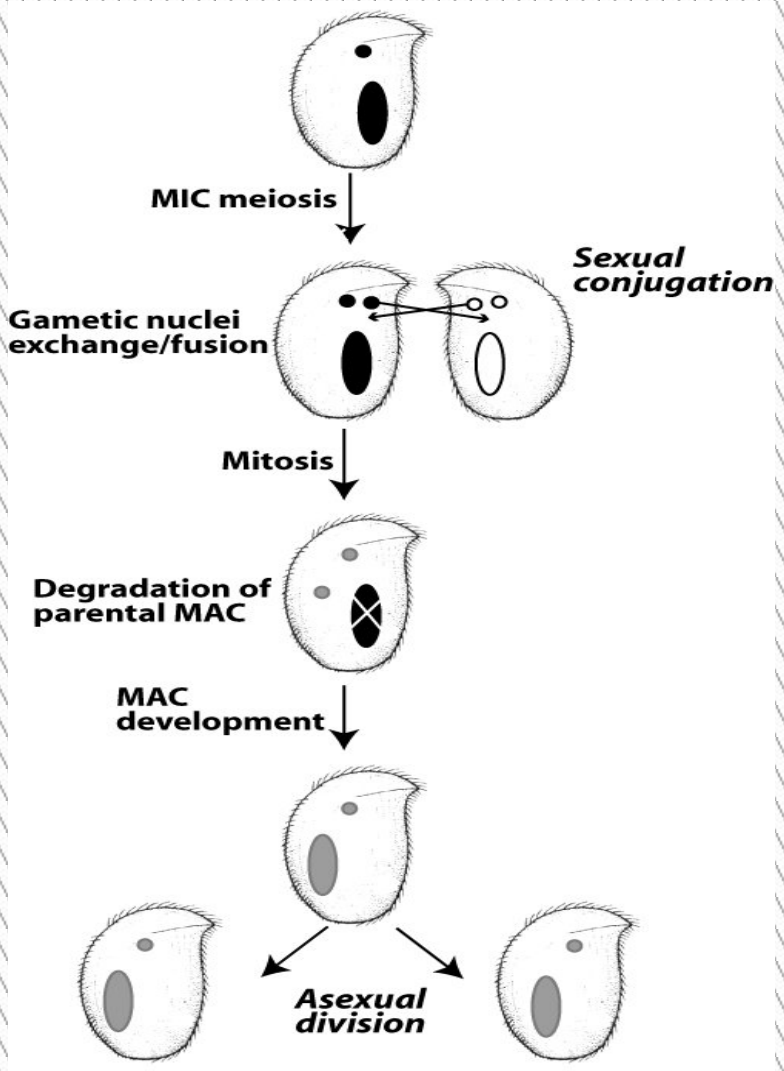


Diagram of Paramecium

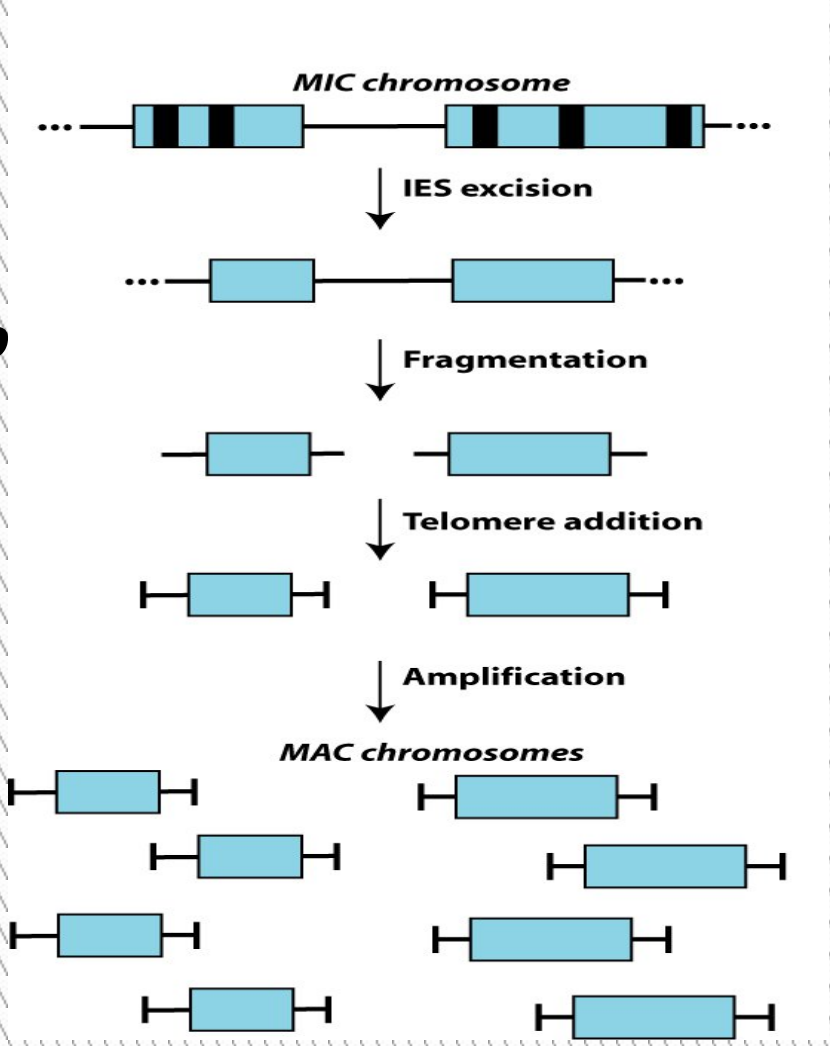
The two nuclei make the life cycle of Paramecium complex

- ***MIC goes through meiosis and the haploid MIC goes through mitosis***
- **Result is 4 haploid MIC, but 2 are degraded**
- **Paramecium exchange 1 haploid MIC**
- ***MIC fuse and form diploid MIC and duplicate via mitosis***
- ***Old MAC degrades and duplicated MIC is processed into new MAC***
- ***In asexual reproduction, the MIC goes through mitosis and the MAC goes through amitosis***



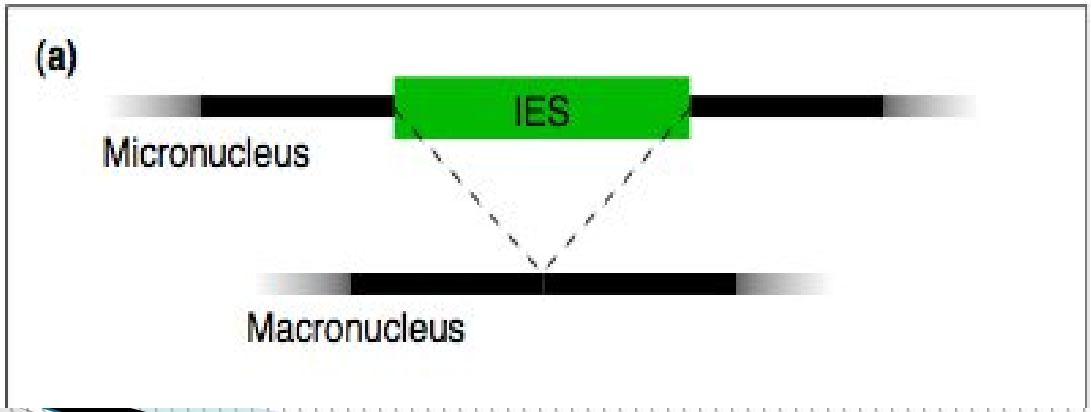
Genome-wide rearrangements of the MAC genome consists of deletion of DNA sequences and chromosome amplification

- ***The developing new MAC loses 10 - 95% of the genome depending on the ciliate***
- ***MAC chromosomes are amplified to a high ploidy level***
- ***Deletion occurs after an initial amplification of the MIC genome but before the ploidy level is reached***



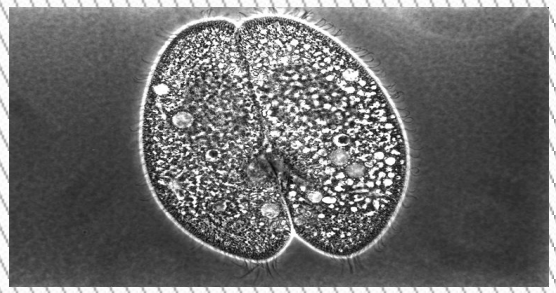
The deletion of DNA is located at specific sequences called internal excised sequences (IES)

- ***IES are located in coding and non-coding regions of the MIC genome***
- ***These sequences are not present in the MAC genome***
- ***At some point in MAC development, the IES sequences are deleted***



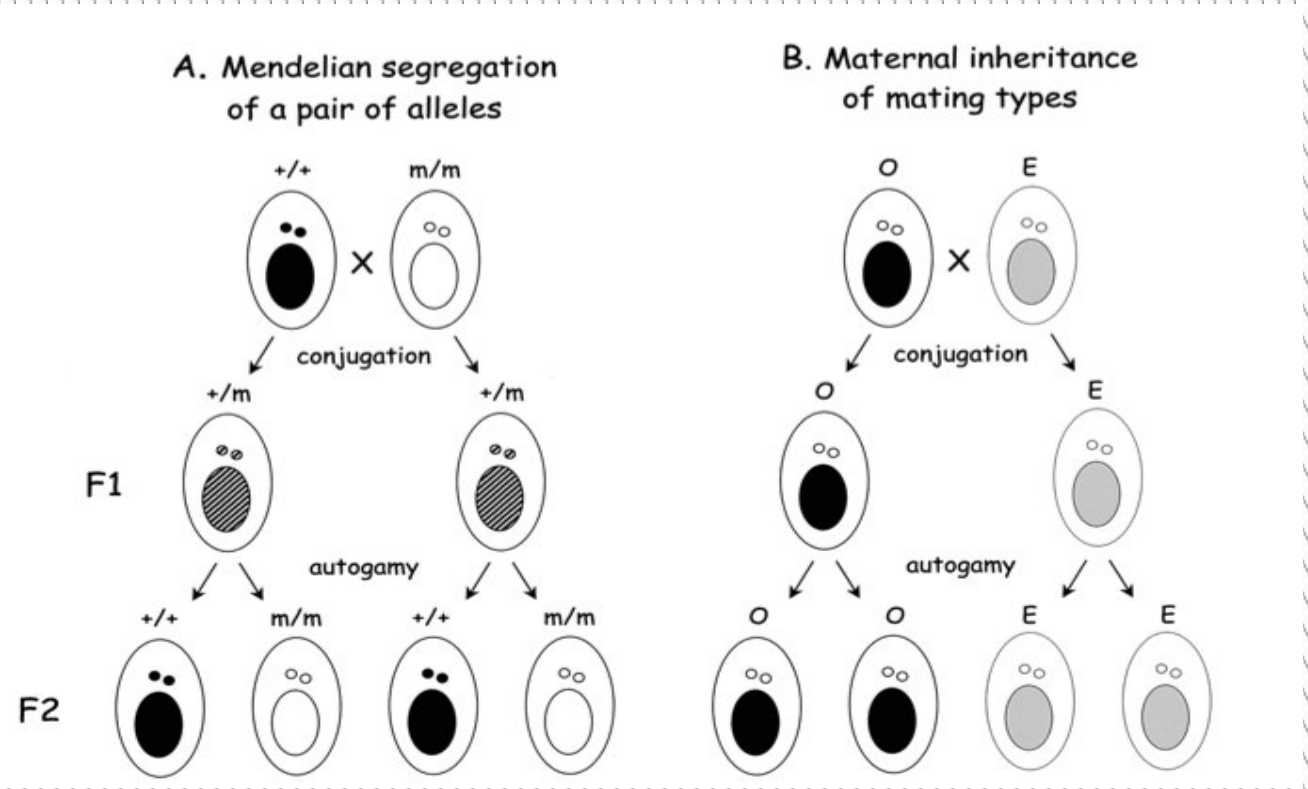
The mating type of Paramecium shows maternal inheritance

- **Paramecium has 2 mating types - O and E**
- ***Both are not determined by genetic differences as they are both produced in homozygous wild-type strains***
- ***Mating type is the same through asexual reproduction but can change after sexual conjugation and MAC formation***
- ***After conjugation O cells mostly produce other O cells and E cells produce other E cells***



Conjugation of P. caudatum by Yanagi

Paramecium mating types do not follow the Mendelian segregation of alleles

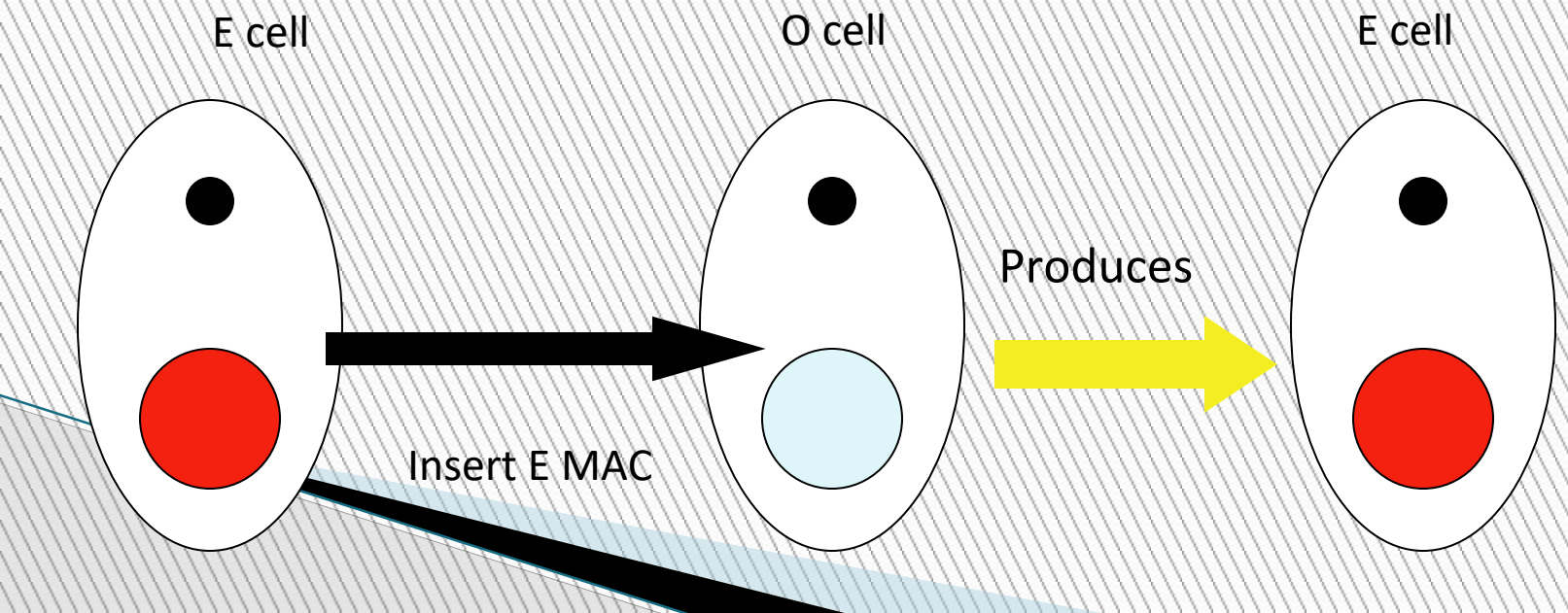


A. ***Mendelian segregation of allelic pairs***
B. ***Maternal inheritance of mating types***

Mating types O and E depends on different states of MAC genome

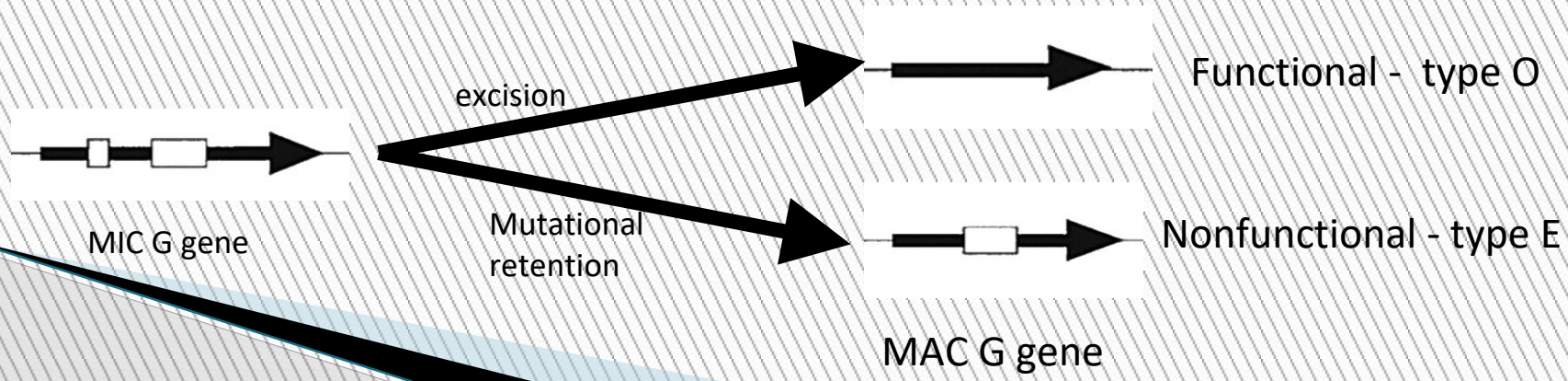
- ***Transferring E maternal MAC into O cell causes the progeny to become E***
- ***Transferring O MAC does not change E cells***

- **O is the default mating type**



This differential state of MAC is dependent on the presence of IES in the MAC

- **The mutation *mTF^{E}* causes *O* cells to become *E***
- ***This mutation affects the excision of an IES on the G gene***
- ***The G gene is a surface antigen and the failure of excision causes a nonfunctional protein to be translated***



Microinjection studies have shown that the presence of an IES sequence in the MAC inhibits the excision of its homologous IES in the MIC

O cells contain G gene in the MAC without its IES (IES-)

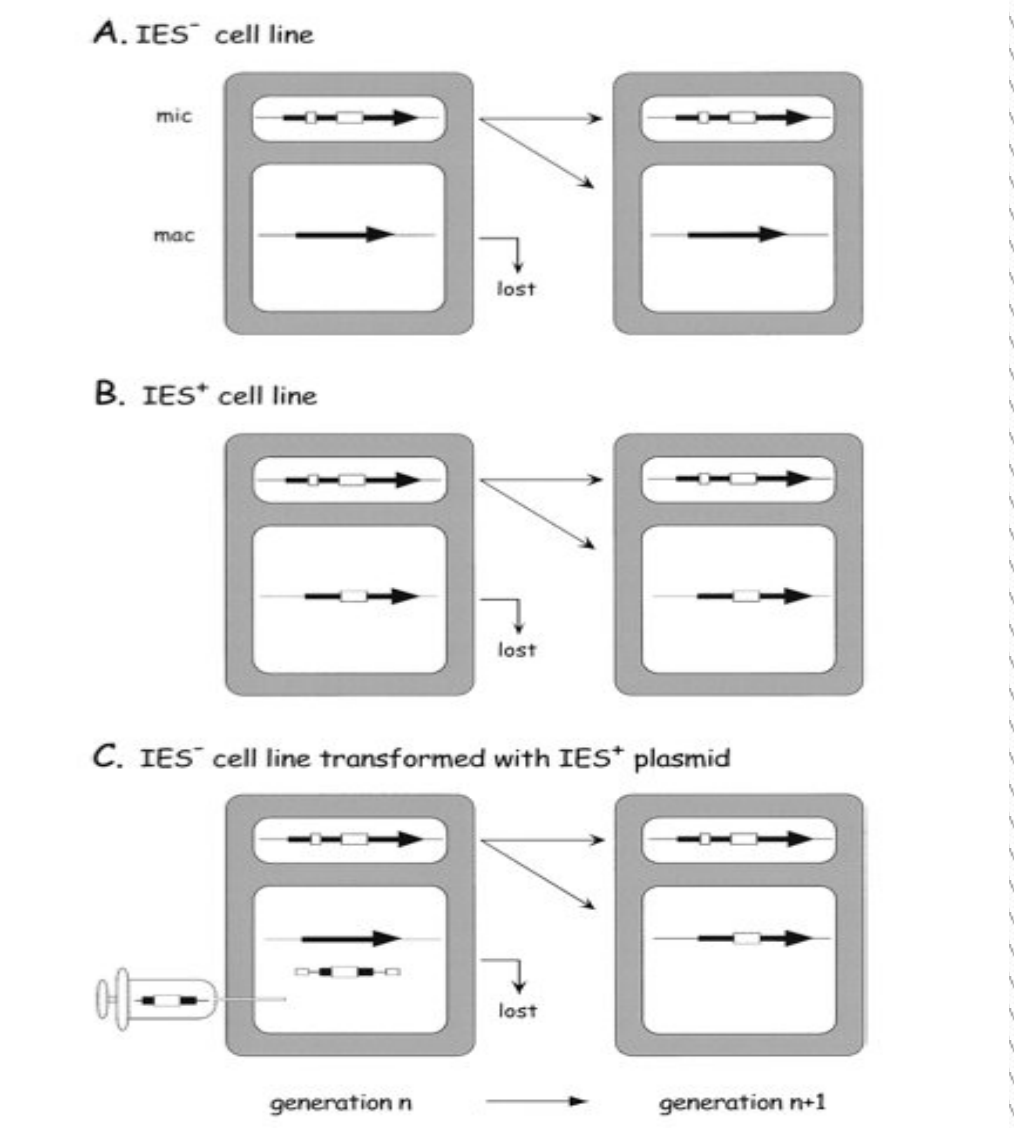
E cells contain the G gene in the MAC with its IES (IES+)

Injecting a plasmid of IES+ G gene into O cell's MAC created the retention of the IES in the MAC of daughter cells

Injection of IES- plasmid did not induce excision

The presence of IES in the MAC causes the retention of the IES in subsequent generations after sexual conjugation

Microinjection of IES+ plasmid retains the IES in the MAC genome after autogamy



Meyer (2002) asked, "How can a sequence introduced in one nucleus affect the excision of the homologous sequence in another nucleus?"

Two models developed

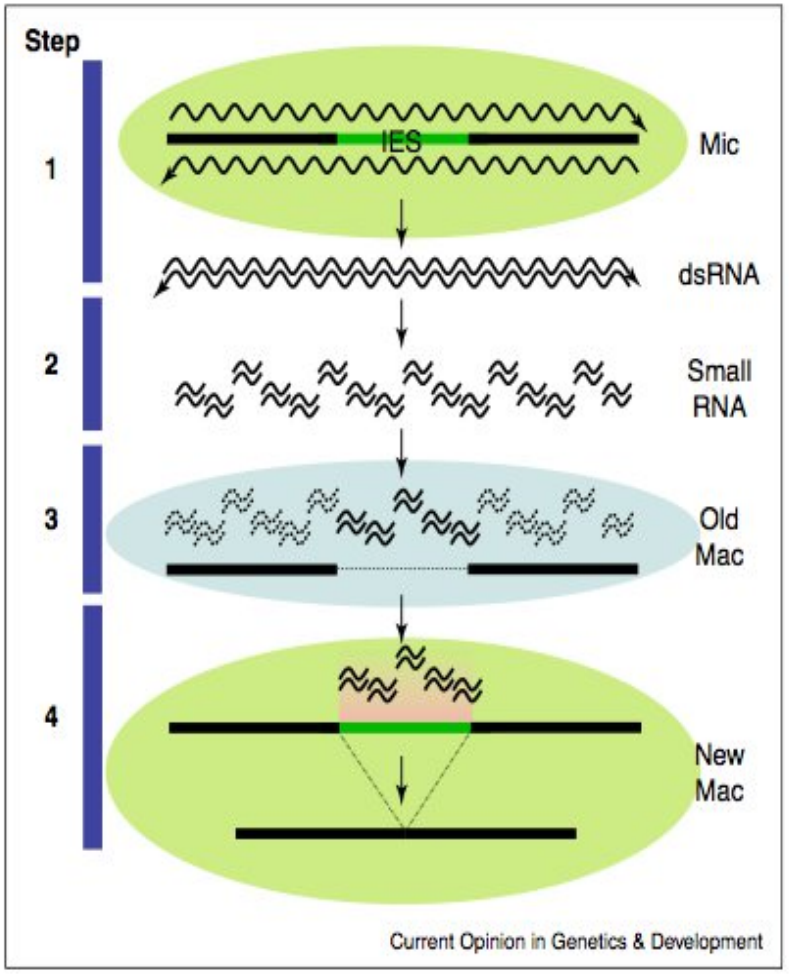
- ***Model 1: Sequence-specific protein factors are required for the excision of the IES in the developing MAC***

- ***The problem with this model is the large number of protein factors needed, about 50,000***

- ***Model 2: Sequence specificity is achieved by homologous nucleic acid (most likely RNA) that is transported from the maternal MAC to the developing MAC***

Mochizuki (2004) explained the Scanning Model, a synthesis of Meyer's model 1 and 2

- ***Entire MIC genome is transcribed bi-directionally and forms dsRNA***
- ***dsRNA is cut up into smaller RNA called scn RNA***
- ***Scn RNA move to the old MAC and any matching homologous sequences are degraded***
- ***Scn RNA that were not degraded move to the developing MAC***
- ***These scn RNAs target homologous sequences which are deleted in an RNA i-like mechanism***



Polymorphic lifestyles

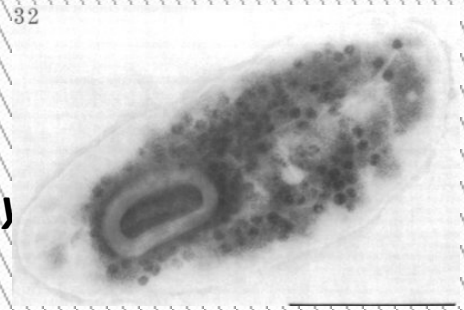
- Have different forms during their life cycle
- May form cysts (vegetative cells) when adverse conditions exist. Cysts are not heat and chemically resistant.

SUMMARY

❖**Paramecium has many instances of cytoplasmic and maternal inheritance**

Paramecium

❖***Kappa bodies are bacterial symbionts that produce a killing factor and they are inherited through the cytoplasm***



Electron micrograph of Kappa

❖***IES excision and retention in the MAC is maternally inherited by the genome present in the MAC***

Ecological importance

- Members of the food chain – Primary or Secondary consumers
- Consume soil bacteria & algae (1 paramecium can ingest 5 million bacteria/day
- Involved in sewage disposal by metabolizing nutrients present to carbon dioxide & water

HARMS

- Cause disease in host organisms
  Malaria – Plasmodium via mosquito
- Toxoplasmosis – Toxoplasma
- African Sleeping Sickness – Trypanosoma via tsetse fly
- Chagas – Toxoplasma
- Vaginitis – Trichomonas
- Giardiasis – Giardia
- 150 million people/year in world contract Malaria & 1.5 mill/year die of it.

FACTS ABOUT PARAMECIUM

"One scientist calculated that if all the progeny of a single *Paramecium* survived, assuming a division rate of once a day, then after 113 days, the mass of paramecia would equal the volume of the Earth! "