EXTRA CHROMOSOMAL INHERITANCE

NON-MENDELIAN INHERITANCE

- Mendelian inheritance patterns
  - Involve genes directly influencing traits
  - Obey Mendel's laws
    - Law of segregation
    - Law of independent assortment
  - Include
    - Dominant / recessive relationships
    - Gene interactions
  - Most genes of eukaryotes follow a Mendelian inheritance pattern

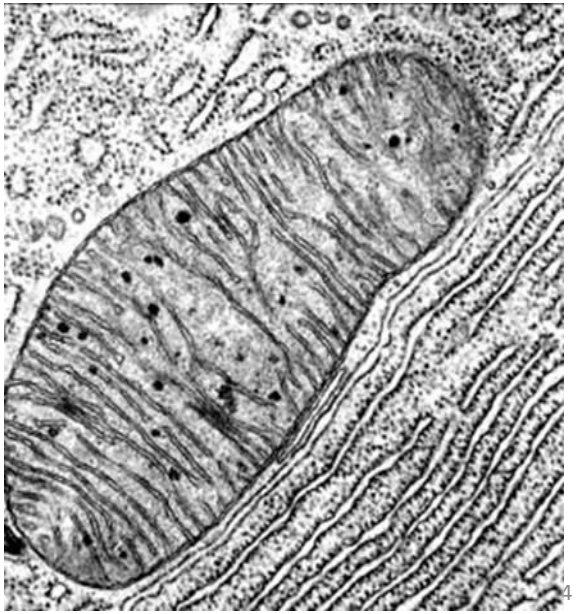
NON-MENDELIAN INHERITANCE

- Many genes do not follow a Mendelian inheritance pattern
  - e.g., Closely linked genes do not follow Mendel's law of independent assortment

    - Extranuclear inheritance

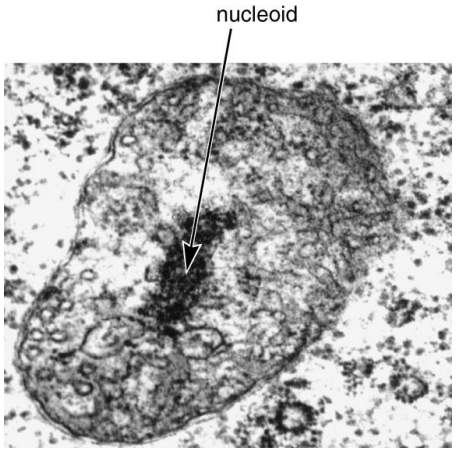
EXTRANUCLEAR INHERITANCE

- Most genes are found in the cell's nucleus
- Some genes are found outside of the nucleus
  - Some organelles possess genetic material
  - Resulting phenotypes display non-Mendelian inheritance patterns
    - "**Extranuclear inheritance**"
    - "**Cytoplasmic inheritance**"

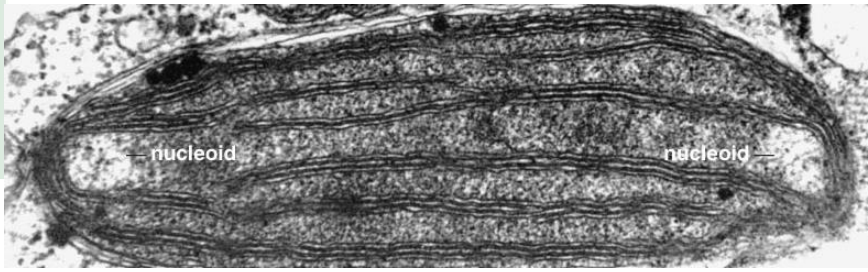


EXTRANUCLEAR INHERITANCE

- Mitochondria and chloroplasts possess DNA
  - Circular chromosomes resemble smaller versions of bacterial chromosomes
  - Located in the nucleoid region of the organelles
    - Multiple nucleoids often present
    - Each can contain multiple copies of the chromosome



Species	Organelle	Nucleoids per Organelle	Total Number of Chromosomes per Organelle
Tetrahymena	Mitochondrion	1	6–8
Mouse	Mitochondrion	1–3	5–6
Chlamydomonas	Chloroplast	5–6	~80
Euglena	Chloroplast	20–34	100–300
Higher plants	Chloroplast	12–25	~60



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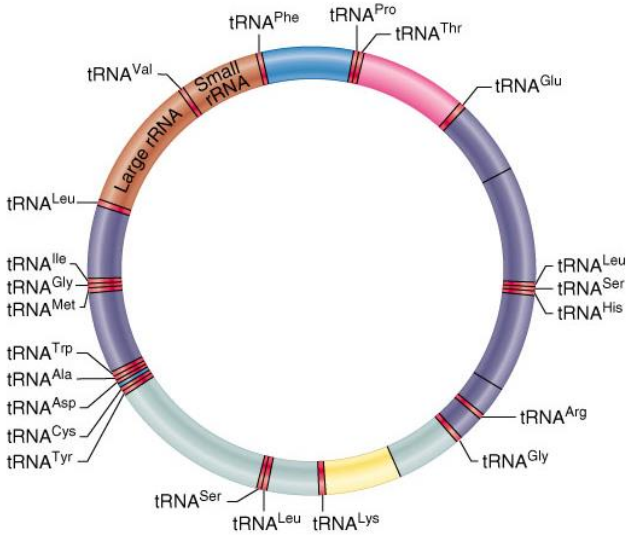
EXTRANUCLEAR INHERITANCE

- Mitochondrial genome size varies greatly among different species
  - 400-fold variation in mitochondrial chromosome size
    - Mitochondrial genomes of animals tend to be fairly small
    - Mitochondrial genomes of fungi, algae, and protists tend to be intermediate in size
    - Mitochondrial genomes of plants tend to be fairly large

EXTRANUCLEAR INHERITANCE

Human mitochondrial DNA is called mtDNA

- Circular chromosome 17,000 base pairs in length
  - Less than 1% of a typical bacterial chromosome
- Carries relatively few genes
  - Genes encoding rRNA and tRNA
  - 13 genes encoding proteins functioning in ATP generation via oxidative phosphorylation



EXTRANUCLEAR INHERITANCE

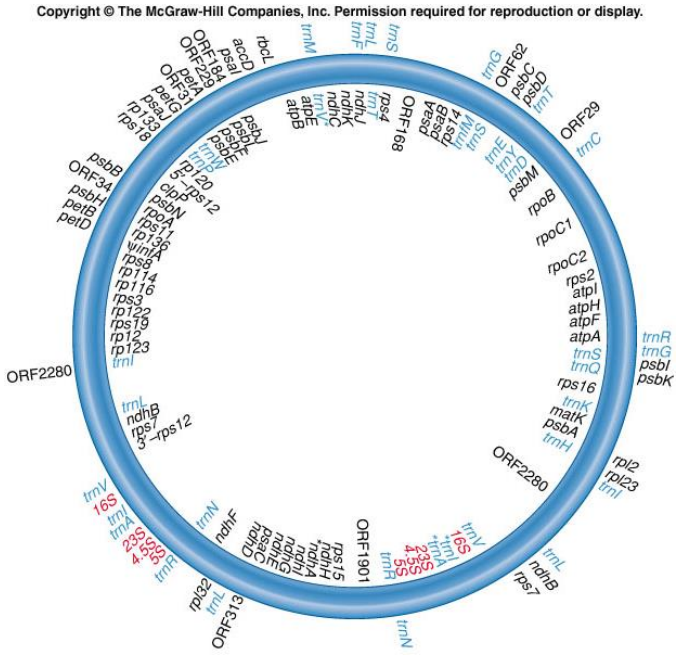
- Most mitochondrial proteins are encoded by genes in the cell's nucleus
  - Proteins are synthesized in the cytosol and transported into the mitochondria

EXTRANUCLEAR INHERITANCE

- Chloroplast genomes tend to be larger than mitochondrial genomes
  - Correspondingly greater number of genes
  - ~100,000 – 200,000 bp in length
  - Ten times larger than the mitochondrial genome of animal cells

EXTRANUCLEAR INHERITANCE

- Chloroplast DNA (cpDNA) of the tobacco plant
  - 156,000 bp circular DNA molecule
  - 110 – 120 different genes
    - rRNAs, tRNAs, and many proteins required for photosynthesis
    - Many chloroplast proteins are encoded in the nucleus



EXTRANUCLEAR INHERITANCE

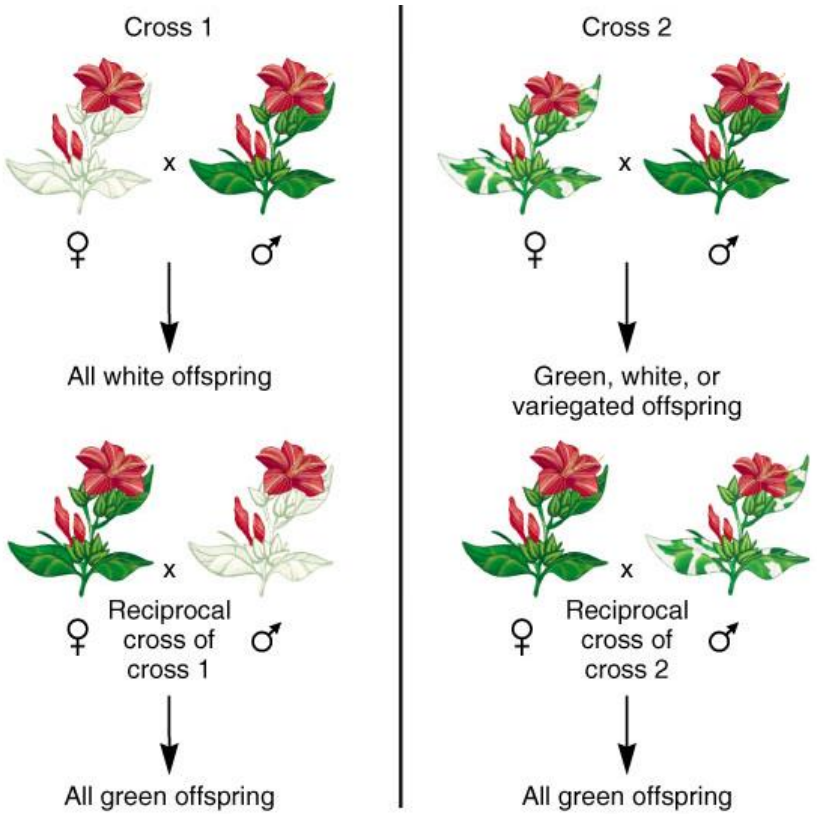
- Most nuclear genes in diploid eukaryotes display Mendelian inheritance patterns
  - Homologous chromosomes segregate during gamete production
  - Offspring inherit one copy of each gene from each parent
- The inheritance pattern of extranuclear genetic material displays non-Mendelian inheritance
  - Mitochondria and plastids do not segregate into gametes as do nuclear chromosomes

EXTRANUCLEAR INHERITANCE

- Pigmentation in *Mirabilis jalapa*
  - The four-o'clock plant
  - Pigmentation is determined by chloroplast genes
    - Green phenotype is the wild-type condition
      - Green pigment is formed
    - White phenotype is due to a mutation in a chloroplast gene
      - Synthesis of green pigment is diminished
    - Cells containing both types of chloroplasts display green coloration
      - Normal chloroplasts produce pigment
      - "Heterotroplasmy"

EXTRANUCLEAR INHERITANCE

- Pigmentation in *Mirabilis jalapa*
  - Pigmentation in the offspring depends solely on the maternal parent
    - "Maternal inheritance"
    - Chloroplasts are inherited only through the cytoplasm of the egg



EXTRANUCLEAR INHERITANCE

- Pigmentation in *Mirabilis jalapa*
  - Cells can contain both types of chloroplasts
    - Coloration is green because pigment is produced
  - Chloroplasts are irregularly distributed to daughter cells during cell division
    - Some cells may receive only chloroplasts defective in pigment synthesis
      - The sector of the plant arising from such a cell will be white
    - Variegated phenotype

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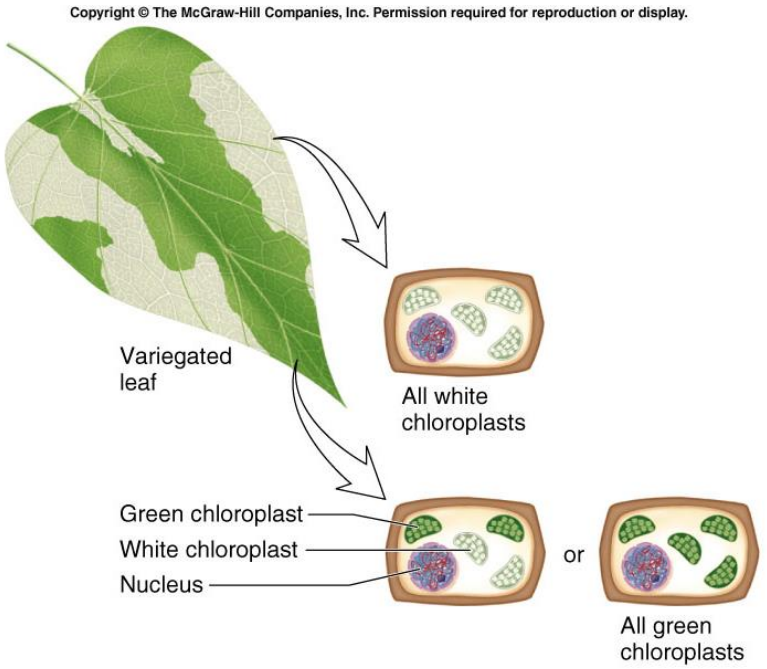

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EXTRANUCLEAR INHERITANCE

- Studies in yeast and unicellular algae provided genetic evidence for extranuclear inheritance of mitochondria and chloroplasts
  - e.g., *Saccharomyces cerevisiae*
  - e.g., *Chlamydomonas reinhardtii*

EXTRANUCLEAR INHERITANCE

- Many organisms are **heterogametic**
  - Two kinds of gametes are made
    - Female gamete tends to be large and provides most of the cytoplasm to the zygote
    - Male gamete is small and often provides little more than a nucleus
  - Mitochondria and plastids are most often inherited from the maternal parent
    - Rarely, mitochondria are provided via the sperm
      - "Paternal leakage"

EXTRANUCLEAR INHERITANCE

- T. M. Sonneborn conducted experiments on Paramecium- one celled protozoa.
- Paramecium reproduces by binary fission or conjugation

EXTRANUCLEAR INHERITANCE

- The protozoan *Paramecia aurelia*
  - Some individuals possess the “killer” trait
    - Secrete the toxin *paramecin*
    - Can kill many strains of paramecia
  - Killer strains contain cytoplasmic particles
    - “Kappa particles”, 0.4 μm long
    - Contain their own DNA
      - Gene encodes paramecin toxin
      - Genes encode resistance to this toxin
  - Kappa particles are infectious
    - Particles in extract from killer strains can infect nonkiller strains
    - Converted to killer strains

EXTRANUCLEAR INHERITANCE

- Certain strains of Drosophila are more sensitive to CO_2.
- Can be affected by much smaller concentration of CO_2 for anesthesia.

CO_2 Sensitive Female X Normal male

Progeny- highly sensitive to CO_2

CO_2 Sensitive Male X Normal Female

Progeny- Normal.