4.4.2: Organellar Inheritance

Learning Objectives

- Explain why genetic information in organelles is passed independently of nuclear DNA.

In eukaryotes, DNA and genes also exist outside of the nuclear chromosomes. Both the chloroplast and mitochondrion have circular chromosomes (Figure \(\PageIndex{1}\)). These organellar genomes are often present in multiple copies within each organelle. In most sexually-reproducing species, organellar chromosomes are inherited from only one parent, usually the one that produces the largest gamete. Thus, in mammals, angiosperms, and many other organisms, mitochondria and chloroplasts are inherited only through the oocyte.

These organelles are likely the remnants of prokaryotic endosymbionts that entered the cytoplasm of ancient progenitors of today’s eukaryotes (endosymbiont theory). These endosymbionts had their own, circular chromosomes, like most bacteria that exist today. Chloroplasts and mitochondria typically have circular chromosomes that behave more like bacterial chromosomes than eukaryotic chromosomes, i.e. these organellar genomes do not undergo mitosis or meiosis.
Figure \(\PageIndex{1}\): A map of the complete mitochondrial chromosome of the woolly mammoth (\textit{Mammuthus primigenius}). The mtDNA that was used to produce this map was obtained from tissue of a mammoth that lived approximately 32,000 years ago. The map shows the position of enzymes encoded on the chromosome including components of the NADH dehydrogenase (ND) complex and cytochrome oxidases (COX), all of which function during energy metabolism in the mitochondrion. The mitochondrial chromosome also encodes various tRNAs and rRNAs used in translation of the genes encoded on this chromosome. Other proteins required by the mitochondrion are encoded in the nuclear genome, and are translated in the cytoplasm and imported into the organelle. (From Rogaev et al, 2006). mtDNA work indicates that mammoths are more closely related to Indian elephants than to either of the African species (Rohland et al, 2010).

### Implications of mitochondrial inheritance

As with nuclear DNA, organellar DNA can be mutated. Cells can have a mixture of hundreds to thousands of organelles with different alleles for genes. Because there are not simply one or two organelles in a cell, terms like heterozygous and homozygous do not apply to this situation and patterns of inheritance can be unpredictable. Some patterns of inheritance that are usually observed for mitochondrial inheritance are:

- Traits can be passed via egg to offspring
- Traits are not passed via sperm to offspring
- Variable penetrance and expressivity are often observed are often due to different proportions of wild type and mutant organelles in the organism of even differing proportions between different tissues in the same organism.

Mitochondrial DNA polymorphisms are also used to investigate evolutionary lineages, both ancient and recent.
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Although organelles are most often inherited through oocytes, exceptions have been identified. Recent studies of cucumber plants (*Cucumis sativus* var. *sativus*) identified SNPs in true-breeding lines and performed reciprocal crosses. The results showed that the chloroplasts were inherited from the maternal parent but that mitochondria are inherited from the male parent.

![Inheritance of organelles and nuclear chromosomes in cucumbers.](https://creativecommons.org/licenses/by/4.0/) Park et al. (2021) via [https://doi.org/10.1038/s41598-021-81988-w](https://doi.org/10.1038/s41598-021-81988-w)

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