Lec9 genetic course

EXTRANUCLEAR INHERITANCE

Outside the nucleus, DNA is found in the mitochondrion and the chloroplast. The genes in these mitochondrial and chloroplast genomes are known as **extranuclear genes, extrachromosomal genes, cytoplasmic genes, non-Mendelian genes, ororganellar genes**.

Extranuclear inheritance or cytoplasmic inheritance refer to the transmission of genes that occur outside the nucleus. It is found in most eukaryotes and is commonly known to occur in cytoplasmic organelles such as mitochondria and chloroplasts or from cellular parasites like viruses or bacteria.

These non-Mendelian, extranuclear genes do not follow the rules of Mendelian inheritance, as do nuclear genes. Cytoplasm is inherited from the mother in many organisms, so the inheritance of extranuclear genes in these organisms is strictly maternal.

Extranuclear inheritance differs from maternal effect in two related respects:

(1) The phenotype in extranuclear inheritance is determined by an individual's organellar gene, whereas the phenotype in maternal effect is determined by a nuclear gene in the mother of the individual; and

(2) An individual's phenotype in extranuclear inheritance matches its genotype, whereas an individual's phenotype in maternal effect does not match its own genotype, instead matching that of its mother.

Types of Extranuclear Inheritance

•Organelle Heredity

1. Mitochondrial DNA (mt DNA)

The genomes of mitochondria (known as mtDNA) of many organisms are circular, double-stranded, supercoiled DNA molecules. Linear mitochondrial genomes are found in some protozoa and some fungi. In general, mitochondrial (mt)DNA contains information for a number of mitochondrial components such as tRNAs, rRNAs, and some of the polypeptide subunits of the proteins cytochrome oxidase, NADHdehydrogenase, and ATPase. The other components found in the

mitochondria—most of the proteins in the organelles— are encoded by nuclear genes and are imported into the mitochondria. These components include the DNA polymerase and other proteins for mtDNA replication, RNA polymerase and other proteins for transcription, ribosomal proteins for ribosome assembly, protein factors for translation, the aminoacyl–tRNA synthetases, and the other polypeptide subunits for cytochrome oxidase, NADH dehydrogenase, and ATPase.

2. Chloroplast DNA (cp DNA)

chloroplast (cp)DNA is double-stranded, circular, and supercoiled. The chloroplast

genome contains genes for the rRNAs of chloroplast ribosomes, for tRNAs, and for some of the proteins required for transcription and translation of the cp-encoded genes (such as ribosomal proteins, RNA polymerase subunits, and translation factors) and for photosynthesis. Most of the proteins found in the chloroplast are encoded by nuclear genes.

3. Plasmids

4. Viral Genomes in a cell or symbiotic particles that have their own genetic material

•Infectious Heredity

The symbiotic or parasitic association of microorganism with a host organism results in transmission of a phenotype in offspring of the host offspring

•Maternal Effect

Maternal effects are the influences of a mother's genotype on the phenotype of her

offspring; **examples include snail coiling and moth pigmentation**, Maternal effects occur when the mother's genotype or phenotype affects the phenotype of her progeny directly. For example, older salmon produce larger eggs which have more nutrients so that their fry are larger at hatching. Mothers can affect offspring phenotype in lots of ways in addition to normal Mendelian inheritance of her alleles at nuclear genes

- Coiling Pattern of Shell in Snail: The effect of maternal genotype on the coiling behaviour in water snail was studied by Sturtevant. There are two types of coiling pattern of shell in snail (Limnaeaperegra), viz., right handed (dextral) and left handed (sinistral). The coiling behaviour is controlled by a single gene. The dextral coiling behaviour is governed by dominant allele D

and sinistral by recessive allele d. When a cross is made between dextral female and sinistral male, it produces dextral snails in F1 as well as in F2. However, in F3 a segregation ratio of 3 dextral and 1 sinistral is observed. Similarly, when a reciprocal cross is made, i.e., sinistral as female and dextral as male, all the snails are sinistral in F1 and dextral in F2. Again in F3 a ratio of 3 dextral and 1 sinistral is observed (Fig.). This indicates that the inheritance of coiling direction in water snail depends on the genotype of female parent and not on its own genotype.

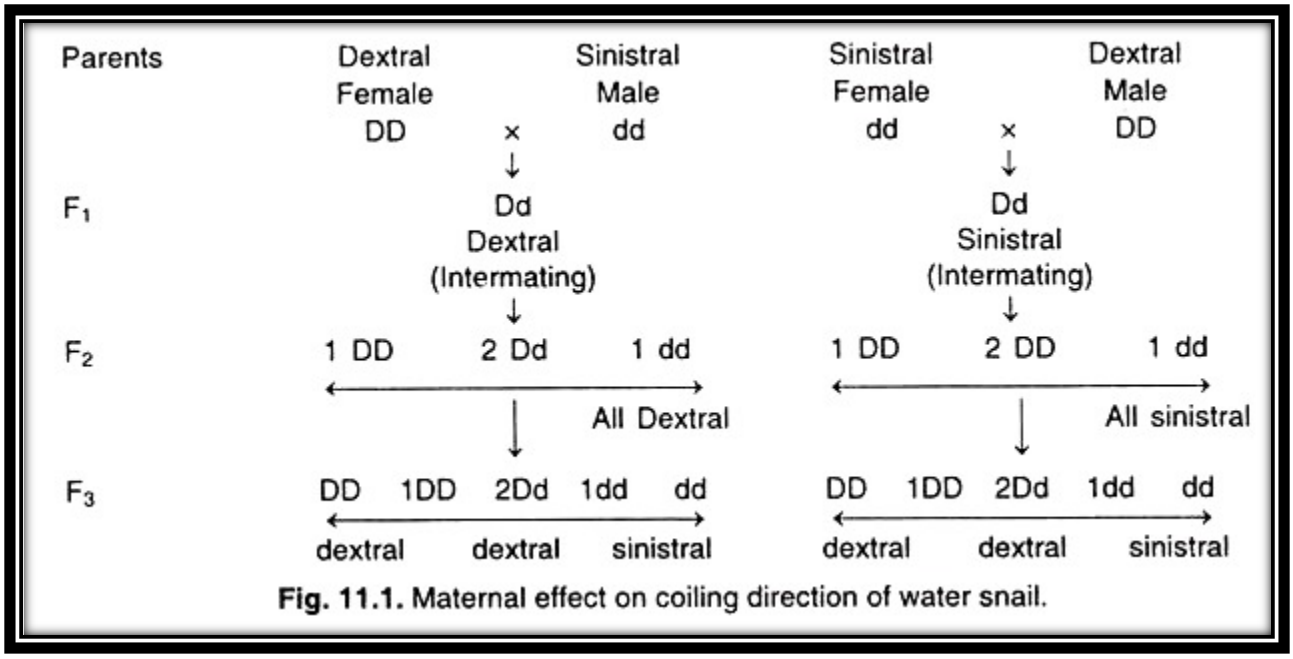

Fig. 11.1. Maternal effect on coiling direction of water snail.

•Genomic Imprinting

Cytoplasmic inheritance is controlled by nonnuclear genomes found in chloroplasts, mitochondria, infective agents, and plasmids. And imprinting is a process in which gene expression depends on the parent from which the gene came. None of these modes of inheritance follow the usual Mendelian rules and ratios.The first case of cytoplasmic inheritance was reported by Conens in 1909 in four ‘o’ clock (Mirabilis jalapa) for leaf colour. Later on, cytoplasmic inheritance was reported by various workers in various organisms.

TABLE 11.2. Differences between cytoplasmic DNA and nuclear DNA

Cytoplasmic DNA	*Nuclear DNA*
1. Found in chloroplasts and mitochondria.	Found in chromosomes.
2. Usually circular except in ciliate protozoa where it is linear.	Linear in eukaryotes and circular in prokaryotes.
3. Synthesis continues throughout cell cycle.	Synthesis occurs only during interphase.
4. Replicates in both chloroplasts and mitochondria.	Replicates in chromosomes.

Four main characteristics of extranuclear inheritance:

1. Ratios typical of Mendelian segregation are not found, because meiosis-based Mendelian segregation is not involved.

2. In multicellular eukaryotes, the results of reciprocal crosses involving extranuclear genes are not the same as reciprocal crosses involving nuclear genes, because meiosis-based Mendelian segregation is not involved. Mitochondrial and chloroplast genes usually show uniparental 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.

3. Extranuclear genes cannot be mapped to the chromosomes in the nucleus.

4. Extranuclear inheritance is not affected by substituting a nucleus with a different genotype.