Genetic Material Possesses Several Key Characteristics

Life is characterized by tremendous diversity, but the coding instructions for all living organisms are written in the same genetic language—that of **nucleic acids.**

Even before **nucleic acids** were identified as the **genetic material**, biologists recognized that whatever the nature of the genetic material, it must possess four important characteristics:

1) **The genetic material must contain complex information.** First and foremost, the genetic material must be capable of storing large amounts of information—instructions for **the traits and functions of an organism**.
2) **The genetic material must replicate faithfully.** Every **organism** begins life as a **single cell**. To produce a complex multicellular organism like yourself, this single cell must undergo billions of cell divisions. At each cell division, the genetic instructions must be accurately transmitted to descendant cells. And when organisms reproduce and pass genes to their progeny, the genetic instructions must be copied with fidelity.
3) **The genetic material must encode the phenotype.** The genetic material (the genotype) must have the capacity to be expressed as a phenotype—to code for traits. The product of a gene is often a protein or an RNA molecule, so there must be a mechanism for genetic instructions in the DNA to be copied into RNAs and proteins.
4) **The genetic material must have the capacity to vary.** Genetic information must have the ability to vary, because different species—and even individual members of the same species—differ in their genetic makeup.

CONCEPTS:

(The **genetic material** must carry large amounts of information, replicate faithfully, express its coding instructions as phenotypes, and have the capacity to vary).

Model Genetic Organism

- Model Genetic Organism: An organism that is widely used in genetic research because it has characteristics, such as short generation time and large numbers of progeny, that make it particularly useful for genetic analysis.
- Through the years, **genetic studies** have been conducted on thousands of different species, including almost all major groups of bacteria, fungi, protists, plants, and animals. Nevertheless, a few species have emerged as **model genetic organisms**—organisms that are widely used in genetic research and that can serve as models for the **genetic systems** of other organisms, **like humans**, which, for various reasons, **may be more difficult to study**.
- **Genetic models** typically have characteristics that make them particularly useful for genetic analysis and about which a tremendous amount of genetic information has accumulated.
- **Six model organisms** that have been the subject of intensive genetic study are *Drosophila melanogaster*, a species of fruit fly; *Escherichia coli*, a bacterium present in the gut of humans and other mammals; *Caenorhabditis elegans*, a soil-dwelling nematode (roundworm); *Arabidopsis thaliana*, the thale-cress plant; *Mus musculus*, the house mouse; and *Saccharomyces cerevisiae*, baker's yeast as shown in Figure 1 below.

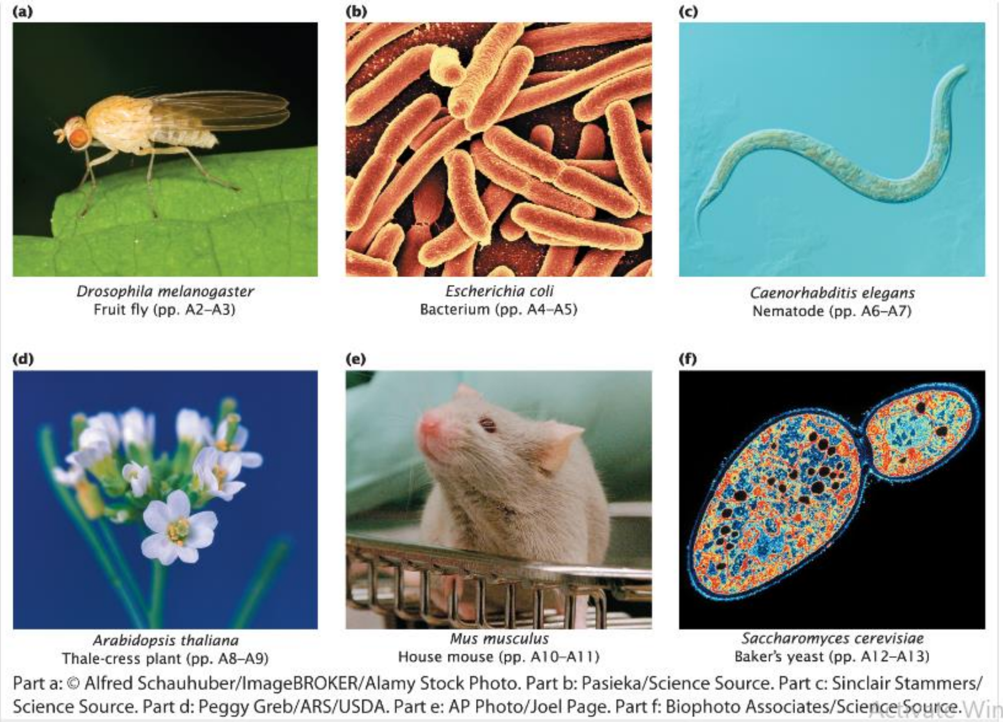


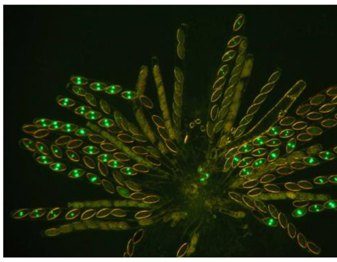
Figure 1: **Model genetic organisms** are species with features that make them useful for genetic analysis.

- However, all possess life cycles and traits that make them particularly suitable for genetic study, including a short generation time, large but manageable numbers of progeny, adaptability to a laboratory environment, and the ability to be housed and propagated inexpensively.
- Other species that are frequently the subjects of genetic research and considered genetic models include *Neurospora crassa* (bread mold), *Zea mays* (corn), *Danio rerio* (zebrafish), and *Xenopus laevis* (clawed frog). Although not generally considered a model genetic organism, *Homo sapiens* has also been subjected to intensive genetic scrutiny; special techniques for the genetic analysis of humans.

Xenopus laevis
(clawed frog)

Danio rerio
(zebrafish)

Zea mays
(corn)



Neurospora crassa
(bread mold)

- The value of **model genetic organisms** is illustrated by the use of **zebrafish** to *identify genes that affect skin pigmentation in humans*.
- For many years, geneticists recognized that differences in pigmentation among human ethnic groups were genetic (See Figure 2), but the genes causing these differences were largely unknown.
- The **zebrafish** has become an important model in genetic studies because it is a small vertebrate that produces many offspring and is easy to rear in the laboratory. The mutant zebrafish called ***golden*** has light pigmentation due to the presence of fewer, smaller, and less dense pigment-containing structures called melanosomes in its cells.

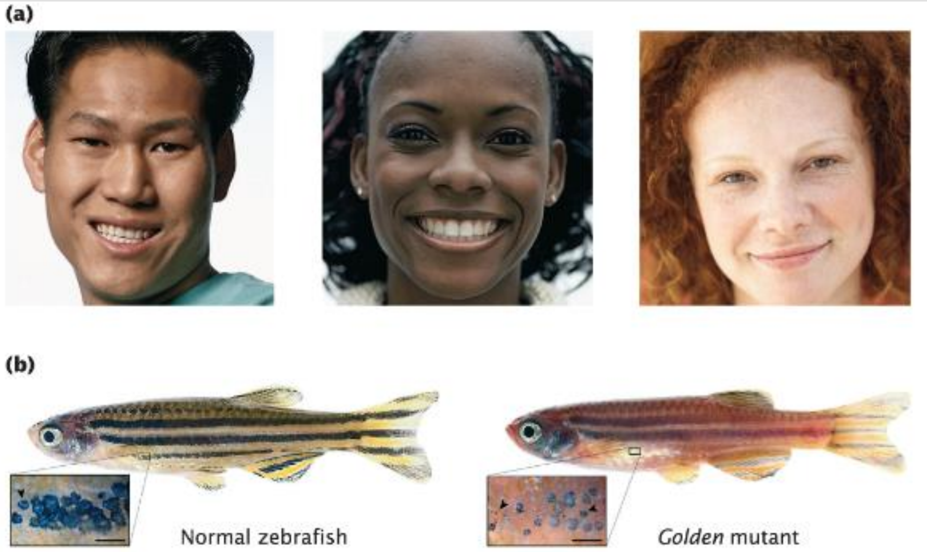


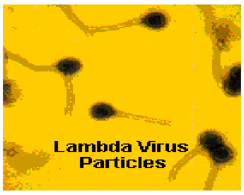
Figure 2: The zebrafish, a model genetic organism, has been instrumental in helping identify genes encoding pigmentation differences among humans. (a) Humans differ in degree of skin pigmentation. (b) The zebrafish golden mutation is caused by a gene that controls the amount of melanin in melanosomes.

- Keith Cheng and his colleagues hypothesized that light skin in humans might result from a mutation that is similar to the ***golden* mutation** in zebrafish. Taking advantage of the ease with which zebrafish can be manipulated in the laboratory, they isolated and sequenced the gene responsible for the ***golden* mutation** and found that it encodes a protein that takes part in calcium uptake by melanosomes.
- They then searched a database of all known human genes and found a similar gene called *SLC24A5* (Solute Carrier Family 24 Member 5), which encodes a protein that has the same function in human cells. When they examined human populations, they found that light-skinned Europeans often possess one form of this gene, whereas darker-skinned Africans, East Asians, and Native Americans usually possess a different form.
- Many other genes also affect pigmentation in humans, as illustrated by the mutations in the *OCA2* (Oculocutaneous albinism type 2) gene formerly called (P gene) that produce albinism among the Hopis (discussed in the Lec.1).

Characteristics of Organisms Used for Genetic Studies

(General Features of an Organism Used for Genetic Studies)

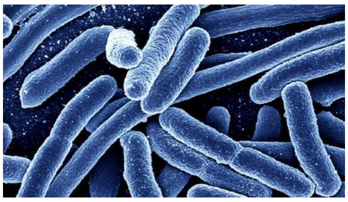
1. Good genetic background.
2. Easy to grow.
3. Controlled mating possible.
4. Can be genetically engineered.
5. Funding available.
6. Variation of Organisms.



Viruses:

- Easily grown in culture and rapid generation time.
- Encode only a few the proteins, which permit a detailed analysis of well-defined system.
- Some viruses have control mechanisms found in eukaryotic species.
- Can be genetically engineered.
- Lack organized chromosome.
- Not all genetic features can be extrapolated to other organisms.

Escherichia coli



- Easily grown in culture and rapid generation time.
- Many mutants available and many genes involved.
- Life cycle very well defined and relatively simple to generate new mutants.
- Can be genetically engineered and contain a rudimentary chromosome.
- Not all genetic features can be extrapolated to higher organisms.

Drosophila melanogaster

- Short generation time for a eukaryotic organism (two weeks).
- Availability of many mutants controlling specific phenotypes.
- Large chromosomes with well-defined cytogenetic system.
- Survives well in the lab and mating's are easily performed.
- Currently, the best organism to study developmental genetics.
- Transposable elements can be manipulated to clone genes and can be genetically engineered.

Homo sapiens (Human):

- Intense public interest and funding available.
- Relatively well-mapped for most eukaryotic species.
- Many diseases (mutant phenotypes) understood clinically.
- Well-defined cytogenetic system and long generation time
- Many traits can only be studied in cell culture.
- Cannot make controlled crosses and cannot be genetically engineered.
- New DNA analysis on the bones of the last **Russian royal family**, indicates the **Royal disease** was indeed **hemophilia**, a rare subtype known as hemophilia B. Hemophilia prevents proteins known as fibrins from forming a scab over a cut or forming clots to stop internal bleeding.

Zea mays (maize):

- Best mapped plant species & many mutants are available that control seed traits
- Well-defined cytogenetic system but not well funded.
- Transposable elements well understood and can be used to clone genes
- Mating's tedious, but produce many (hundreds) of progeny
- Only three generations per year and cannot be easily genetically engineered

Arabidopsis thaliana:

- Small genome with little repetitive DNA and short generation time (six weeks).
- Many mutants rapidly becoming available.
- Mating's tedious, but produce many (thousands) of progeny.
- Currently, an intensely investigated organism and can be easily genetically engineered.

- **Mouse** has been used for many genetic studies because it is a mammal that is a relatively good model for human gene expression. A good example is the globin genes, protein that carry oxygen in blood cells. *The genetic and molecular organization of the mouse and human genes are quite similar*, they have the same number of exons and have the introns located at the same amino acid residue in the transcript.
- Furthermore, the order of the **multigene family** is conserved. **Yeast** has also been well studied. Although this species is a good model system, this is not the reason that it was first investigated. The primary reason was because of its role in brewing.

Concept check as Homework Activity: Would the horse make a good model genetic organism? Why or why not?