Unit 4
Model organisms

Study Material
(For online class)
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DSE-4
Research Methodology

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What is a Model Organism?

- When researchers look for an organism to use in their studies, they look for several traits. Among these are size, generation time, accessibility, manipulation, genetics, conservation of mechanisms, and potential economic benefit. Selected bacteria, fungi, plants or animals that can be bred and studied with simple methods and are therefore of great importance for biological and biomedical research. Model organisms are, as being used as a model, usually the first organisms of a kingdom whose entire genome was decoded. This further pushes their research capabilities.

Model organism:

- Model organisms are those organisms which are extensively studied to understand a specific phenomenon, expecting that the knowledge gained can be applied to other species as well.
- The model organisms are studied as an example for other species and/or biological phenomena that are more difficult to study directly.
- Models organisms are *in vivo* model for research purpose and consists of different non-human species because human experimentation is unfeasible and unethical for experiment.

- Some of the common model organisms :
- *E. coli*– used as model for bacterial genetics and metabolism
- *Saccharomyces cerevisiae* (Yeast): used as model for cell and molecular biology
- *Dorsophila:* used as model for developmental biology
- Zebra fish: used as model for embryonic development

Typical characteristics of model organisms

- Development to maturity should be rapid
- Should have the ability to be easily manipulated
- Should have a short life span
- Should produce a large number of offspring
- Must have a sequenced genome, in addition to being well understood.
- Model organisms are often small, have a short generation time, are easy to work with in large numbers and cheap to maintain.

History of Model Organisms

- In the middle of the 19th century Biologists like Charles Darwin and Gregor Mendel and their respective work on natural selection and the genetics of heredity were a corner stone for genetic research in general.
- Darwin's notebooks from 1837 shows one of the first evolutionary tree sketches. In the 20th century this elemental work on plants and free-living animals continued in laboratories where *Drosophila, E.coli* and lab mice where introduced as new model organism. These organisms have led to many advances in the past century.

Reasons to turn to nontraditional models

- The group of organism used as model is not a fix term.
- New ones emerge; and replace olders over time.
- Example: The first studies on ends of chromosomes - the telomeres – were done in ciliated protozoan *Tetrahymena*. Each *Tetrahymena* cell has a huge number of tiny, linear chromosomes and so each cell is far more enriched with telomere sequences than is a typical eukaryotic cell.

- Model organisms are found among prokaryotes, protists, fungi, plants and animals, and even though they represent only a small fraction of the biodiversity existing on Earth, the data resulting from their study forms the core of biological knowledge to date.

Model Organisms in different Kingdoms

Kingdom	**Model organism**		**Kingdom**	**Model Organism**
Prokaryote	*Bacillus subtilis*		Animals	*Xenopus laevis*
	Escherichia coli			*Killifish (Oryzias latipes)*
Fungi	*Aspergillus nidulans*			*Platynereis dumerilii*
	Neurospora crassa			*Caenorhabditis elegans*
	Schizosaccharomyces pombe			Zebrafish *(Danio rerio)*
	Saccharomyces cerevisiae			*Drosophila melanogaster*
Algae	*Chlamydomonas reinhardtii*			
Plants	*Arabidopsis thaliana*			
	Oryza sativa			
	Zea may			

Model Organisms in Plant physiology

- *Arabidopsis thaliana:*
- *A. thaliana* is the most researched model organism in fundamental research in plant molecular genetics. Its small stature and genome and short generation time facilitates rapid genetic studies.
- This plant is also used as a tool for understanding the physiology of many traits, including flower development and light sensing.

- *Chlamydomonas reinhardtii*:
- *C. reinhardtii* is a single-cell green alga. It is a model organism for research on cell movement and recognition, photosynthesis, flagella and motility, regulation of metabolism and response to starvation.
- *Zea mays:*
- Maize is a diploid monocot and one of the most used cereal grains. It has been a keystone model organism for basic research in genetics, molecular biology and agronomy for nearly a century. Maize is used to study developmental physiology, epigenetics, pest resistance, heterosis, quantitative inheritance, and comparative genomics.

- <u>*Oryza sativa*</u>:
- Rice (*Oryza sativa*) is one of the most important crops in the world. It has one of the smallest genomes of any cereal species. Besides genetic study, effect of biotic and abiotic stress on rice and responses against it was reported. . In order to combat vitamin A deficiency, Golden rice was created by transforming rice with two beta-carotene biosynthesis genes by modifying its biosynthetic pathway.
- <u>*Brachypodium distachyon:*</u>
- *Brachypodium distachyon* is used as a model organism in studies on different physiological prosessess including vernalisation and flowering time pathways and seed storage proteins, responses to drought stress and pathogens. The roles of microRNAs involved in drought and cold stress responses have also been studied using this organism.

- Besides these, some other plants are also used as model for plant physiological studies-
- *Antirrhinum majus* has been used as a model plant for the molecular analysis of transposons , asymmetric floral development and floral pigmentation
- *Nemesia strumosa* Benth, has many characteristics that make it a potential model plant for the study of asymmetric floral development

Model Organisms in Genetics

- Bacteria(*Escherichia coli*) :
- Bacteria are unicellular free living organisms. They have many features which make them suitable objects for genetical investigations.
- The bacterium *Escherichia coli* has been most widely studied for genetical investigations.
- It has been named after its discoverer, Theodore Escherich, the species name has been derived from the colon where it resides.

- The concept of genetic recombination was discovered by Beadle and Tatum on *E. coli* and operon concept was developed on *E. coli* by Jacob and Monod (1961) for which they were awarded Nobel Prize for Physiology or Medicine in 1965. They studied lactose metabolism in lac region of *E. coli.* Later on, operon model was studied in several other organisms.

- 2. Bacteriophages:
- Work on phage genetics was initiated in early thirties independently by Delbruck (a physicist), Schlesinger and Burnet. Most significant contribution in phage genetics was made by Delbruck. He along with Luria and Hershey discovered genetic recombination in phages in 1940s.
- Later on phages have been extensively used as tools for the study of gene structure and function. The principle of transduction was invented by the study of bacteriophages.
- Benzer (1955) divided gene into cistron, recon and muton working on r-II locus of T4 phage of *E. coli*.

- 3. *Drosophila*:
- The fruitfly (*Drosophila melanogaster*) has been widely used for genetic studies.
- Drosophila has several features like Short life cycle, Produces large number of offspring, Easy for handling, Can be raised under controlled conditions, Inexpensive to maintain and Variation and recombination capacity which make them Model organisms for genetic study.

- *Drosophila* was first used for the study of linkage by Morgan (1910). Concepts of sex linked inheritance, sex determination; chromosomal aberrations, multiple alleles and mutation were developed by the study of *Drosophila*.

- Muller used *Drosophila* for the study of induced mutations. The low chromosome number (2n = 8) of fruitfly has greatly facilitated the construction of linkage maps.

- 4. *Neurospora*:
- *Neurospora crassa* a fungus, has been studied on large. The important concept of one gene one enzyme was developed on *Neurospora for* which Beadle and Tatum won Nobel Prize for physiology or medicine in 1958.

- According to this hypothesis each gene controls the reproduction, function and specificity of a particular enzyme. The study of *Neurospora* also contributed to the understanding of linkage and crossing over. Concept of negative interference was also developed from studies on *Neurospora*.

- 5. Corn (2n = 20):
- The maize plant has been extensively used for genetic and cytogenetic studies. Linkage maps have been constructed for all the ten chromosomes. Genetical studies on maize have significantly contributed to the advancement of concepts related to linkage, chromosomal aberrations, mutation, sex determination, cytoplasmic inheritance and heterosis. Mc Clintock discovered jumping genes working on maize.

- 6. Garden Pea:
- The basic principles of heredity were discovered on garden pea by Mendel. Later on the coupling and repulsion concepts of linkage were also discovered by Bateson and Punnett (1905) on garden pea. The interaction of non-allelic genes was observed in garden pea.

- *Populus* sp.
- *Populus* is a genus used as a model in forest Genetics and woody plant studies. It has a small genome size, grows very rapidly, and is easily transformed. The genome sequence of *P. trichocarpa* sequence is available.

- Cell and Molecular Biology

- *Escherichia coli*
- Because of their comparative simplicity, prokaryotic cells (bacteria) are ideal models for studying many fundamental aspects of Cell and molecular biology. The most thoroughly studied species of bacteria is *E. coli*, which has long been the favored organism for investigation of cellular structure and the basic mechanisms of molecular genetics. Most of our present concepts of cell and molecular biology—including understanding of DNA structure and replication, the genetic code, gene expression, and protein synthesis—derive from studies of this bacterium.

- *Saccharomyces* spp. :
- Although bacteria have been an invaluable model for studies of many conserved properties of cells, they obviously cannot be used to study aspects of cell structure and function that are unique to eukaryotes. Yeasts, the simplest eukaryotes, have a number of experimental advantages similar to those of *E. coli*. Consequently, yeasts have provided a crucial model for studies of many fundamental aspects of eukaryotic cell biology.

- Yeast mutants have been important in understanding many fundamental processes in eukaryotes, including DNA replication, transcription, RNA processing, protein sorting, and the regulation of cell division. The unity of molecular cell biology is made abundantly clear by the fact that the general principles of cell structure and function revealed by studies of yeasts apply to all eukaryotic cells.

- *Dictyostelium discoideum:*
- *Dictyostelium discoideum* is a cellular slime mold, which, like yeast, is a comparatively simple unicellular eukaryote. The genome of Dictyostelium is approximately ten times larger than that of *E. coli*—more complex than the yeast genome but considerably simpler than the genomes of higher eukaryotes. It is a highly mobile cell, and this property has made *Dictyostelium* an important model for studying the molecular mechanisms responsible for animal cell movements .
- For example, introducing the appropriate mutations into *Dictyostelium* has revealed the roles of several genes in cell motility.

- *Caenorhabditis elegans*
- The unicellular eukaryotes *Saccharomyces* and *Dictyostelium* are important models for studies of eukaryotic cells, but understanding the development of multicellular organisms requires the experimental analysis of plants and animals, organisms that are more complex. The nematode *Caenorhabditis elegans* possesses several notable features that make it one of the most widely used models for studies of animal development and cell differentiation.

- The simplicity of *C. elegans* has enabled the course of its development to be studied in detail by microscopic observation. Such analyses have successfully traced the embryonic origin and lineage of all the cells in the adult worm.
- Genetic studies have also identified some of the mutations responsible for developmental abnormalities, leading to the isolation and characterization of critical genes that control nematode development and differentiation. Importantly, similar genes have also been found to function in complex animals (including humans), making *C. elegans* an important model for studies of animal development.

- *Drosophila melanogaster*
- Extensive genetic analysis of *Drosophila* has uncovered many genes that control development and differentiation. Studies of *Drosophila* have led to advances in understanding the molecular mechanisms that govern animal development, particularly with respect to formation of the body plan of complex multicellular organisms. As with *C. elegans*, similar genes and mechanisms exist in vertebrates, validating the use of *Drosophila* as a major experimental model in contemporary developmental biology.

- *Arabidopsis thaliana*
- *Arabidopsis* is notable for its genome of only about 130 million base pairs—a complexity similar to that of *C. elegans* and *Drosophila*. In addition, *Arabidopsis* is relatively easy to grow in the laboratory, and methods for molecular genetic manipulations of this plant have been developed. These studies have led to the identification of genes involved in various aspects of plant development, such as the development of flowers. Analysis of these genes points to clear similarities between the mechanisms that control the development of plants and animals, further emphasizing the fundamental unity of cell and molecular biology.

- Cultured cells:
- The use of cultured cells has allowed studies of many aspects of mammalian cell biology, including experiments that have elucidated the mechanisms of DNA replication, gene expression, protein synthesis and processing, and cell division. Moreover, the ability to culture cells in chemically defined media has allowed studies of the signaling mechanisms that normally control cell growth and differentiation within the intact organism. The specialized properties of some highly differentiated cell types have made them important models for studies of particular aspects of cell biology. Muscle cells, for example, are highly specialized to undergo contraction, producing force and movement. Because of this specialization, muscle cells are a crucial model for studying cell movement at the molecular level.

- *Xenopus laevis*
- The frog *Xenopus laevis* is an important model for studies of early vertebrate development. *Xenopus* eggs are unusually large cells, with a diameter of approximately 1 mm. Because those eggs develop outside of the mother, all stages of development from egg to tadpole can be readily studied in the laboratory. In addition, Xenopus eggs can be obtained in large numbers, facilitating biochemical analysis. Because of these technical advantages, Xenopus has been widely used in studies of developmental biology and has provided important insights into the molecular mechanisms that control development, differentiation, and embryonic cell division.

- Mouse:
- Among mammals, the mouse is the most suitable for genetic analysis. Recent advances in molecular biology have enabled the production of transgenic mice, in which specific mutant genes have been introduced into the mouse germ line, so that their effects on development or other aspects of cell function can be studied in the context of the whole animal.

Model Organisms in Biochemistry

- *Escherichia coli*
- The nutrient mixtures in which *E. coli* divide most rapidly include glucose, salts, and various organic compounds, such as amino acids, vitamins, and nucleic acid precursors. However, *E. coli* can also grow in minimal media.The ability of *E. coli* to carry out biosynthetic reactions of synthesizing all their own amino acids, nucleotides, and other organic compounds in simple defined media has made them extremely useful in elucidating the biochemical pathways involved. Thus, the rapid growth and simple nutritional requirements of *E. coli* have greatly facilitated fundamental experiments in both molecular biology and biochemistry.

- *Chlamydomonas reinhardtii*
- *C. reinhardtii* is a unicellular green alga used to study photosynthesis, flagella and motility, regulation of metabolism, cell-cell recognition and adhesion, response to nutrient deprivation, and many others.
- *Dictyostelium discoideum*
- *Dictyostelium* provide an important model for studies of cell signaling system and cell-cell interactions.

- Most model organisms of Molecular biology , physiology, metabolism are treated as Model organisms in Biochemistry also.