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WHAT ARE MODEL ORGANISMS AND WHY DO WE USE THEM IN BIOLOGY RESEARCH?

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YOUNG REVIEWERS:

KENNEDY
AGE: 12

MERIEM
AGE: 14

SELIM
AGE: 13

How do scientists discover new things about living organisms, like a new life pathway or a cycle? They do it using model organisms. Model organisms, which are simple organisms that have important similarities with humans, help with many discoveries in biology. Model organisms are readily available and easy to grow in the lab. The remarkable advances made in healthcare and modern medicine are mainly due to model organisms. Scientists use model organisms to learn about human biology simply because research on humans is both difficult and in some cases is not appropriate or ethical. With model organisms, things ranging from one tiny cell to an entire system (like a single celled bacterium to a multicellular organism such as mouse) can be studied. This article introduces the most popular plant, invertebrate, and vertebrate model organisms used in research labs today.

MODEL ORGANISMS IN RESEARCH

Why do researchers prefer to use some animals and plants over humans in their scientific studies? Research on human subjects is difficult and unethical as participants may not fully understand the research and its associated risks. The research may also involve procedures that may cause physical or emotional harm to the participants. In addition, there may be a breach of confidentiality and invasion of privacy of the participants. To avoid these difficulties and ethical concerns, researchers use **model organisms** in biology research. Certain species, called model organisms, are used because they are simple to grow and study, and because they have important similarities with humans or other organisms of interest (Figure 1). Similarities allow researchers to make use of life mechanisms that are shared across these species. The study of model organisms has been critical in expanding our knowledge of biology. Model organisms help us to understand complex life systems in detail. Much of our knowledge about genes, evolution, ecology, and behavior has come from studying model organisms. An illustration of some common plant and animal model organisms are provided in Figure 2.

MODEL ORGANISMS

Non-human species/organisms that scientists use in the lab to investigate and understand biological processes.

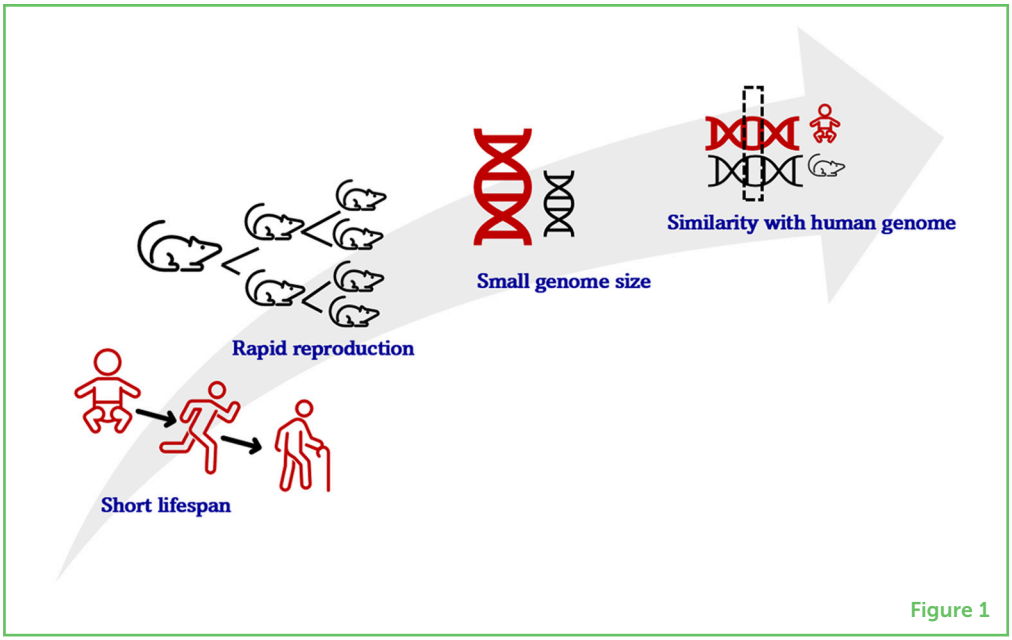

Figure 1

Important characteristics of model organisms used in scientific research. Model organisms are valuable in scientific investigations as they help scientists to understand various biological processes. Model organisms have specific characteristics, including a short lifespan, rapid reproduction rates, small genomes that are easy to study and change, and genomes that are similar to the human genome. These traits make model organisms ideal for studying specific scientific questions or diseases.

PEA PLANTS TO STUDY PLANT GENETICS

The field of **genetics** investigates the "passing down" or inheritance of traits from one generation to the next. There has been much progress and discovery in this exciting field throughout the years. Gregor Johann Mendel is an important character in genetics history. In 1886, he wrote an important paper about how genes are passed down from parents to their offspring, and this work paved the way for

GENETICS

Study of how certain features pass from one generation to the next generation through genes.

Figure 2

An illustration of some common animal and plant model organisms.

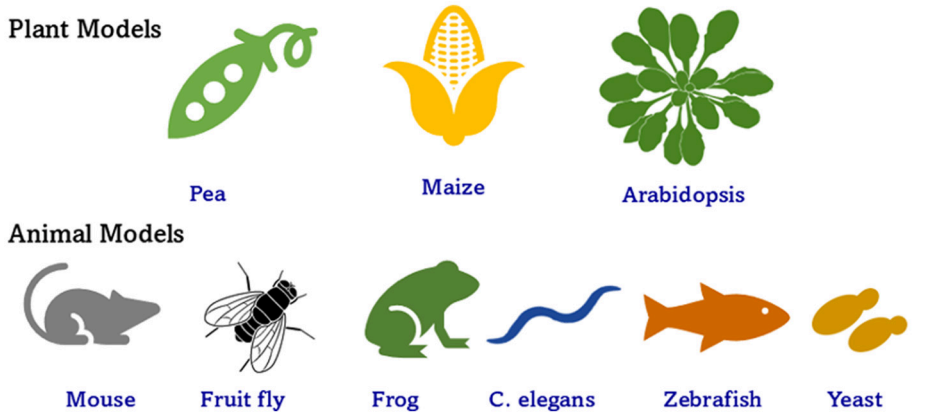

Figure 2

modern research in genetics. There was not much known about the field of genetics during Mendel's time, and it was not until the early 20th century that researchers started to make good progress. Mendel studied the pea plant *Pisum sativum* L. as a model organism. Because it is easy to grow, has clear visible traits such as flower color, seed color, seed size, and stem length, this plant was an excellent genetics lab specimen.

MAIZE AS A MODEL TO STUDY PLANT HETEROSIS

Zea mays, commonly known as corn or maize, is one of the most studied plant species. Corn is a major staple crop worldwide. It is pollinated by the wind and has distinct male and female flowers, making it easy for scientists to work with and study. It is a great model for understanding why an offspring of two different species might have superior traits compared to either parent. This phenomenon is called **heterosis**. Corn plants also produce a lot of pollen, making it easy for researchers to create mutant plants—by treating corn pollen with chemicals to examine how mutations affect plant properties [1]. In 1983, maize researcher Barbara McClintock won the Nobel Prize for discovering "jumping genes", also called **transposons**, in maize. Transposons are DNA segments that can move from one place to another within the **genome**. She used maize plants to study how transposons influence the activity of genes and genome evolution. Maize, sadly, must be grown outdoors with farm equipment, which makes it hard for researchers in cities to study it. It also takes 3–4 months to get seeds from one generation of maize crops, which makes research slow.

HETEROSIS

When the offspring of two different plants are stronger, healthier or grow faster than their parent plants.

TRANSPOSONS

Pieces of DNA nucleotides that can move around the cell's genome.

GENOME

The complete set of an organism's genetic material, including all its genes and non-gene sequences, which determine its structure and function.

MOUSE-EAR CRESS AS A MODEL TO STUDY PLANT GENETICS

In 1943, Friedrich Laibach presented Arabidopsis, also called mouse-ear cress, as a model organism for studying plant genetics. *Arabidopsis*

thaliana is a small weedy plant found growing across Europe, North America, and Asia, and is great for studying plant genetics [2]. Arabidopsis has a short life cycle (about 4–6 weeks), making it convenient for lab work. Certain bacteria can be used to change the genes of Arabidopsis in petri dishes or containers under lab conditions. This allows research into how different versions of a gene affect a plant's characteristics. Unique types of Arabidopsis can be saved as seeds, making it easy to maintain thousands of variants.

FRUITFLIES AS A MODEL TO STUDY HUMAN GENETICS

The pea plant taught scientists basic genetics, but to study humans, researchers preferred species that were more similar to us than plants are. So, the fruit fly called *Drosophila melanogaster* became a valuable model organism. It is simple and inexpensive to grow these insects in a lab, and they are found all over the world. The fruit fly has a short life cycle of about 8–10 days, making it ideal for genetic research [3]. The study of fruit flies led to the discovery that genes are physical features of **chromosomes**. Thomas Hunt Morgan and his team raised Drosophila in a lab called "The Fly Room". By determining the distances between genes on fruit fly chromosomes, Morgan's group learnt about gene function [4]. Researchers use fruit flies to study human development, due to the similiarties between the fruit fly genome and the human genome. One aspect of development is the **metamorphosis** of fruit flies from egg to adult, which can teach scientists about conserved genes and pathways and inform our understanding of how organs and organ systems such as the nervous and digestive systems develop. Also, fruit flies' digestive and nervous systems are similar to those of mammals. They are also great study subjects because they have about 100,000 brain cells, providing them with intelligence and complex behavior [3].

CHROMOSOMES

Thread-like structures in the cell nucleus that carry genetic information in the form of genes (genes are made up of DNA), which are the fundamental units of heredity.

METAMORPHOSIS

A biological process involving a striking change in an organism's form and structure, such as the change from a caterpillar to a butterfly.

ZEBRAFISH AS A MODEL TO STUDY HUMAN DEVELOPMENT

The zebrafish, *Danio rerio*, is a popular model organism for studies of genetics and development. There are many similarities between these freshwater fish and fruit flies. They only have a 3-month life cycle, are cheap and simple to grow in the lab, and they reproduce rapidly. However, unlike fruit flies, zebrafish are vertebrates and hence have more in common with humans—including muscles, hearts, kidneys, and eyeballs. Just like developing fruit flies, zebrafish have a translucent (see-through) phase. This helps scientists to see their interior development. For example, using a low-power microscope, scientists can see blood vessels forming in a zebrafish embryo. Thus, zebrafish are an excellent model organism for studying the development of the heart and blood vessels. They are also widely used to study the development of other complex structures such as the

eyes and brain or processes like cancer. Zebrafish are also valuable for studying how chemicals and toxins affect brain growth [5].

EMERGING MODEL ORGANISMS AND ARTIFICIAL INTELLIGENCE

The fields of genetics and biology have greatly benefited from the model species we have described, and the number of new model organisms is growing. Each model organism helps researchers gain vital insights into the systems that control life and how organisms form and function. Recently, technological advances have enabled scientists to explore a wider range of non-traditional organisms that were previously less studied [6]. These include:

- *Volvox*: A green alga used to study the evolution of multicellular life.
- *Nematostella*: A sea anemone used to understand body plan development.
- *Tardigrade*: also known as a water bear, used to study survival in extreme conditions.
- *Oxytricha*: a ciliate used to study genome complexity and DNA modifications.
- *Naegleria*: an amoeba used for studying phagocytosis—a process by which living cells engulf other cells or particles.
- *Physcomitrella*: a moss plant used to study plant evolution and development.
- *Fission Yeast*: a fungus used to study cell division and genetics.
- *Mosquito*: an insect used to study vector-parasite interactions and immune responses to parasites.

To be widely used as a model organism, an organism's chemical building blocks (sequence of the nucleotides that make up an organism's DNA) should be known. Knowing this DNA sequence allows scientists to make changes to the genes to study biological processes. Scientists also consider other factors to decide which model organism to use for a particular study, mainly involving whether the organism's features and processes will allow them to answer their specific scientific questions. **Artificial intelligence** (AI) can help scientists choose the right model organism for a particular study. AI can do this by comparing the similarity of the genomes between the potential model organism and the organism the scientist is asking their questions about. In the future, AI might even be able to put together genome sequences from different model organisms to create a new model organism that is ideal for a scientist's purposes.

ARTIFICIAL INTELLIGENCE

Computer systems developed by humans that can perform tasks involving learning and problem-solving abilities.

In summary, model organisms share genetic similarities with humans, making them useful for studying human diseases. They are easy to grow in a lab and are more accessible to genetic manipulations for

studying gene function. They are also less expensive and yield faster results, accelerating the discovery process in biology research.

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YOUNG REVIEWERS

KENNEDY, AGE: 12

Kennedy grew up always loving math and science staying curious and asking questions about everything. Her current hobbies include dance, hanging out with friends and family, and trying new foods. When she grows up she wants to be a professional dancer or a traveling nurse.

MERIEM, AGE: 14

I have a deep love for nature, especially the wonders of the sea and the fascinating diversity of animals. I am particularly intrigued by the mysteries of the ocean—what lies beneath its depths and how various creatures live and thrive in our world. My passions span science, art, and reading, as I enjoy exploring both the logical and creative sides of life. If there is one thing I would love to truly understand, it is the human brain—how it functions, what happens when we sleep, and the intricate process behind the creation of dreams.

SELIM, AGE: 13

Drawing my way through life, I believe in the power of creativity and knowledge—whether it is through a sketch or a new fact, a little bit curious, but always ready to learn and connect.

AUTHORS

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Arpita Yadav is a post-doctoral scholar at The Penn State University, State College (Pennsylvania, United States) where she is trying to understand plant cell wall structure, growth, and mechanics. Her doctoral studies focused on how certain proteins control developmental and stress responses when *Arabidopsis thaliana* is exposed to ultraviolet radiation. She loves doing research, but she is equally devoted to sharing scientific knowledge with the public. She enjoys walking in nature and hiking.

MANEESH LINGWAN

Maneesh Lingwan is a Research Scientist at Donald Danforth Plant Science Center. He is particularly interested in plant biochemistry and analytical methods to decode cell metabolism. His current research focuses on understanding plant lipid metabolism to enhance crop oil production. In addition to his research, Maneesh encourages and educates younger students by providing insightful information about careers in STEM fields and helping them navigate opportunities.

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Saumitra Dey Choudhury is a neurogeneticist by training and is interested in understanding how nerve connections form and become functional. He uses the fruit fly nerve-muscle connection to address questions pertaining to nerve growth and maintenance. He holds a Master's degree in Biochemistry from Bangalore University and earned his Ph.D. from IISER Bhopal. After a post-doctoral stint at the National Institutes of Health (USA), he currently works as a senior

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