Module 6

Microbiology & Drug Discovery

Dr. Pravin D. Patil

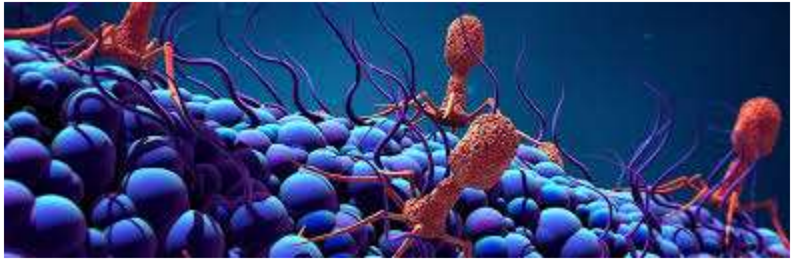
Objectives:

- Classification

- based on Energy and Carbon Utilization

- based on Nitrogenous Excretion

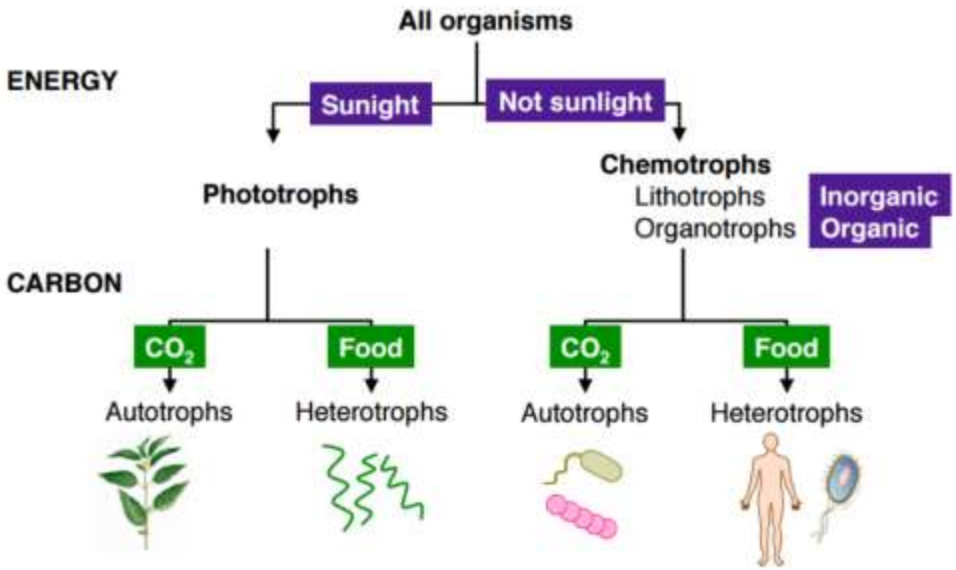
- Microbiology
- Types of microbes
- Model organisms & Drug discovery



Types of classifications:

- Classification **based on Energy and Carbon Utilization**

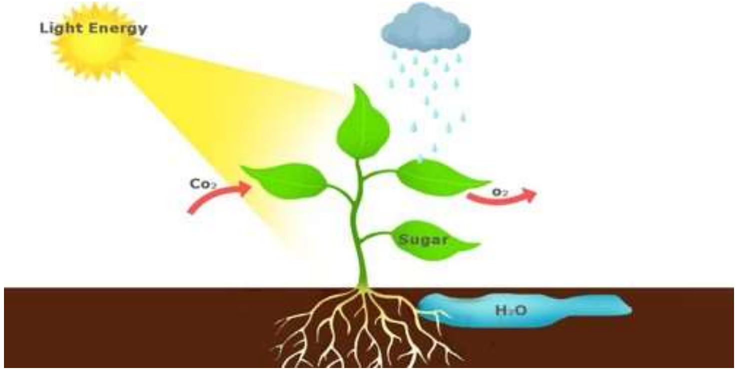
  - Autotrophs
  - Heterotrophs
  - Lithotrophs



Types of classifications:

Autotrophs:

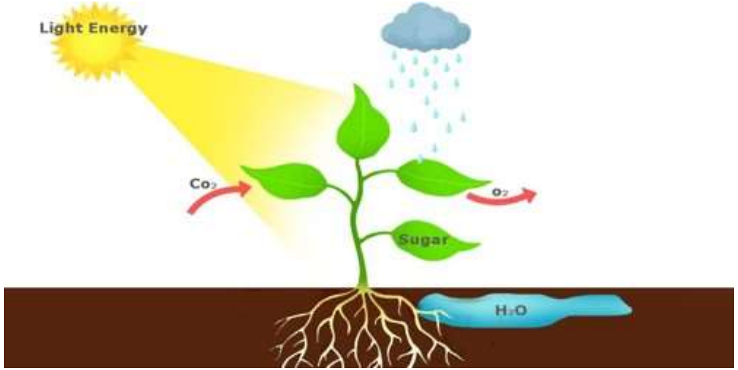
- An autotroph or producer, is an organism that produces complex organic compounds (such as carbohydrates, fats, and proteins) from simple substances present in its surroundings, generally using energy from light (photosynthesis) or inorganic chemical reactions (chemosynthesis).



Types of classifications:

Autotrophs:

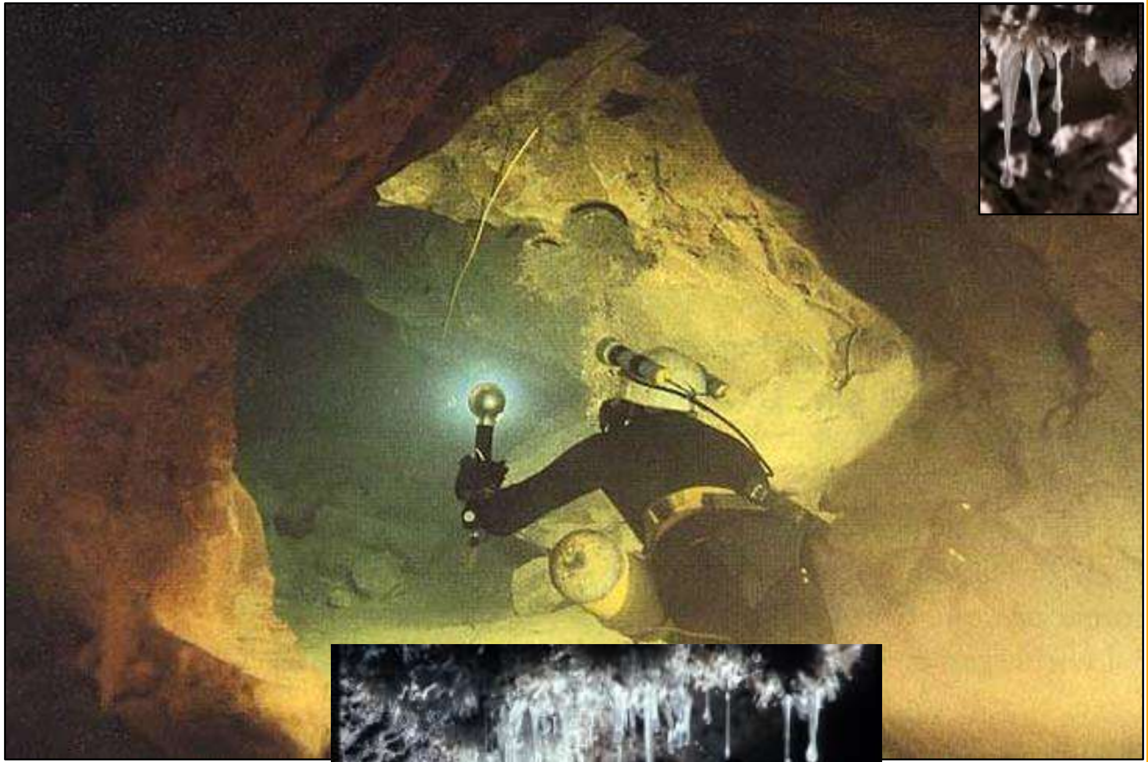
- They are the producers in a food chain, such as plants on land or algae in water (in contrast to heterotrophs as consumers of autotrophs). They do not need a living source of energy or organic carbon.
- Autotrophs can reduce carbon dioxide to make organic compounds for biosynthesis and also create a store of chemical energy.



Types of classifications:

Autotrophs:

- Most autotrophs use water as the reducing agent, **but some can use other hydrogen compounds,** such as hydrogen sulfide.



Types of classifications:

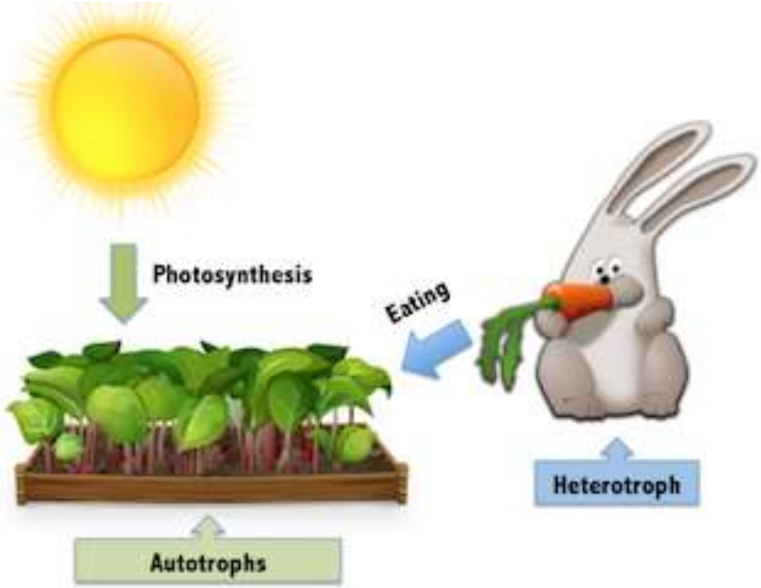
Autotrophs:

- Autotrophs can reduce carbon dioxide to make organic compounds for biosynthesis and also create a store of chemical energy.
- Some autotrophs, such as **green plants and algae**, are phototrophs, meaning that they convert electromagnetic energy from sunlight into chemical energy in the form of reduced carbon.
- All phototrophs either use **electron transport chains** or direct **proton pumping** to establish an electrochemical gradient.

Types of classifications:

Heterotrophs:

- A heterotroph (Ancient Greek héteros = "other" plus trophe = "nutrition") is an organism that cannot produce its own food, relying instead on the intake of nutrition from other sources of organic carbon, mainly plant or animal matter.
- In the food chain, heterotrophs are primary, secondary and tertiary consumers, but not producers.



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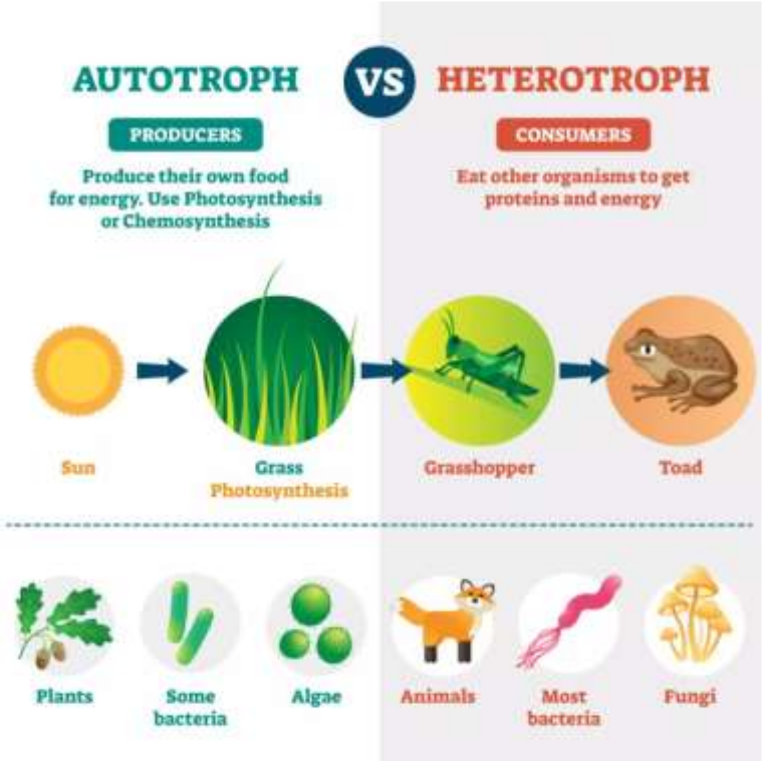
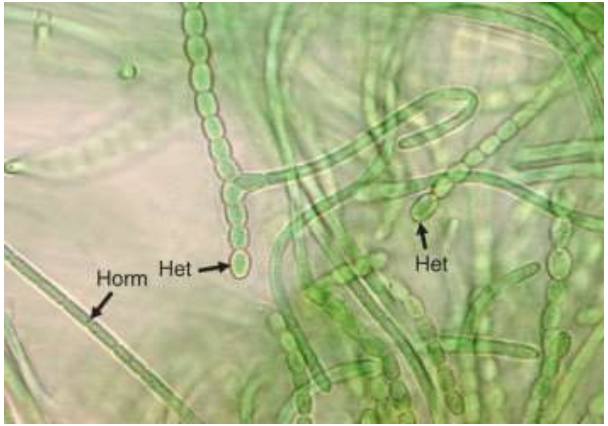


Types of classifications:

Heterotrophs:

- Ninety-five percent or more of all types of living organisms are heterotrophic, including all animals and fungi and some bacteria and protists.
- If the heterotroph uses chemical energy, it is a **chemoheterotroph** (e.g., humans and mushrooms). If it uses light for energy, then it is a **photoheterotroph** (**e.g., green non-sulfur bacteria**).



Green non-sulfur bacteria

Types of classifications:

- **Lithotrophs** belong to either the domain Bacteria or the domain Archaea. The term "lithotroph" was created from the Greek terms 'lithos' (rock) and 'troph' (consumer), meaning "eaters of rock".
- Lithotrophs are a diverse group of organisms using inorganic substrate (usually of mineral origin) to obtain reducing equivalents for use in biosynthesis (e.g., carbon dioxide fixation) or energy conservation (i.e., ATP production) via aerobic or anaerobic respiration.

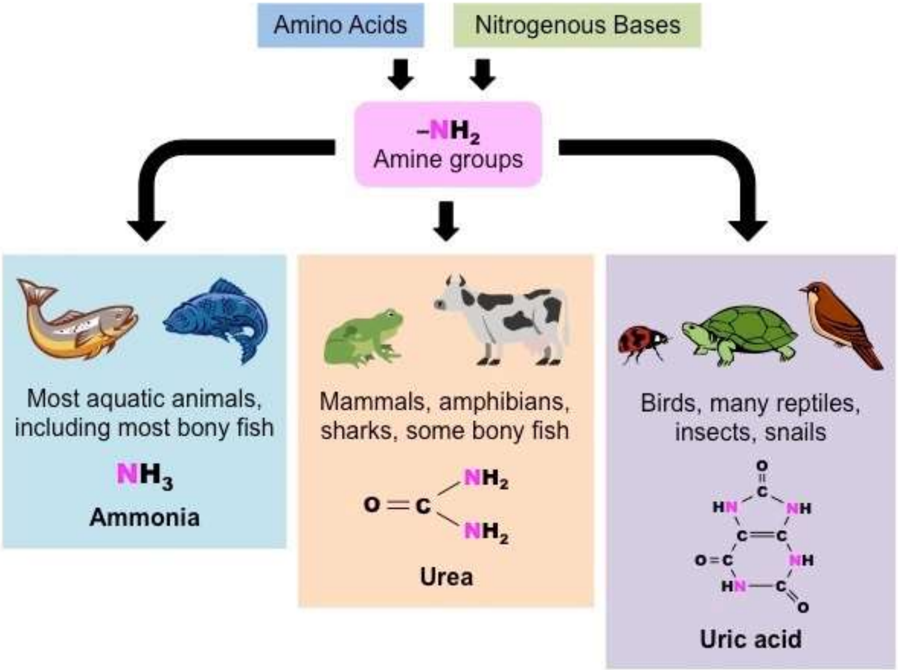
Types of classifications:

Lithotrophs:

- Known chemolithotrophs are exclusively microorganisms; no known macrofauna possesses the ability to use inorganic compounds as energy sources.
- Example: **Purple sulfur bacteria** that transform **sulfide into sulfur**, nitrifying bacteria that use ammonia and convert it into nitrite or use nitrite to produce nitrate, and hydrogen bacteria that oxidize hydrogen to water.

Types of classifications:

- Classification based on **Nitrogenous Excretion**
  - Ammonotelic
  - Ureotelic
  - Uricotelic



Types of classifications:

- Classification based on Nitrogenous Excretion

- Digestion of food and catabolism of protein result in the production of wastes, including various nitrogen-containing products, particularly ammonia, urea, and uric acid.
- Prolonged dehydration leads to accumulation of nitrogen waste, which causes death if not removed or diluted.
- The nitrogen compounds through which excess nitrogen is eliminated from organisms are called nitrogenous wastes or nitrogen wastes.
- They are ammonia, urea, uric acid, and creatinine. All of these substances are produced from protein metabolism. In many animals, the urine is the main route of excretion for such wastes; in some, the faeces is.

  - Ammonotelic
  - Ureotelic
  - Uricotelic

Types of classifications:

- Classification based on Nitrogenous Excretion

Ammonotelic

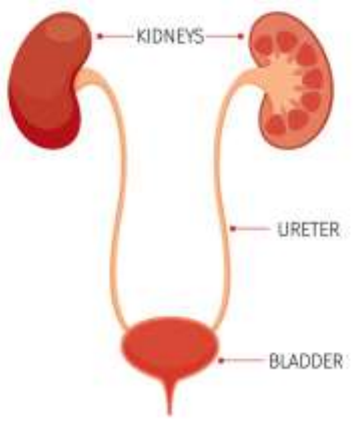
- Ammonotelism is the excretion of **ammonia and ammonium ions.** Ammonia (NH_3) forms with the oxidation of amino groups ($-NH_2$), which are removed from the proteins when they convert into carbohydrates.
- It is a very toxic substance to tissues and extremely soluble in water. Only one nitrogen atom is removed with it. **A lot of water is needed for the excretion of ammonia**, about 0.5 L of water is needed per 1 g of nitrogen to maintain ammonia levels in the excretory fluid below the level in body fluids to prevent toxicity.
- Thus, the **marine organisms excrete ammonia directly into the water and are called ammonotelic.**
- Ammonotelic animals include protozoans, crustaceans, platyhelminths, cnidarians, poriferans, echinoderms, and other aquatic invertebrates

Types of classifications:

- Classification based on Nitrogenous Excretion

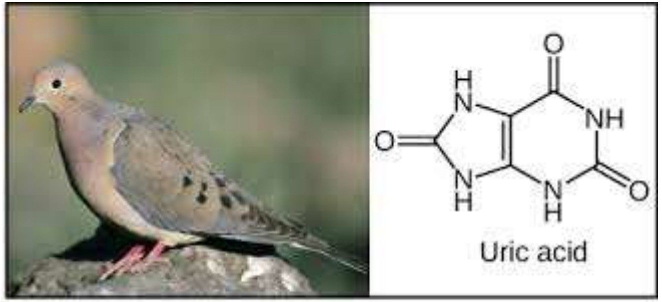
Ureotelic

- The **excretion of urea is called ureotelism.** Land animals, mainly **amphibians and mammals, convert ammonia into urea, a process which occurs in the liver and kidney.**
- These animals are called ureotelic. Urea is a less toxic compound than ammonia; two nitrogen atoms are eliminated through it and less water is needed for its excretion.
- It requires 0.05 L of water to excrete 1 g of nitrogen, approximately only 10% of that required in ammonotelic organisms



Types of classifications:

- Classification based on Nitrogenous Excretion



Uricotelic

- Uricotelism is the **ridding of excess nitrogen using uric acid**. This method is used by **birds and diapsids, insects, lizards, and snakes, and these animals are uricotelic.**
- Uric acid is less toxic than ammonia or urea. It contains four nitrogen atoms and only a small amount of water (about 0.001 L per 1 g of nitrogen) is needed for its excretion.
- Uric acid is the least soluble in water and can be stored in cells and body tissues without toxic effects.
- A single molecule of uric acid can remove four atoms of nitrogen making uricotelism more efficient than ammonotelism or ureotelism.
- **Uricotelic organisms typically have white pasty excreta. Some mammals including humans excrete uric acid as a component of their urine but it is only a small amount.**

Effects on Human beings:

Microorganisms

Beneficial

Food

Bread, Wine, Cheese, Yoghurt, Vinegar

Industrial applications

Enzymes, Amino acids, Vitamins, Antibiotics, Vaccines, Pharmaceutical industries, Sewage treatment

Agriculture

Recycling of elements, Nitrifying bacteria

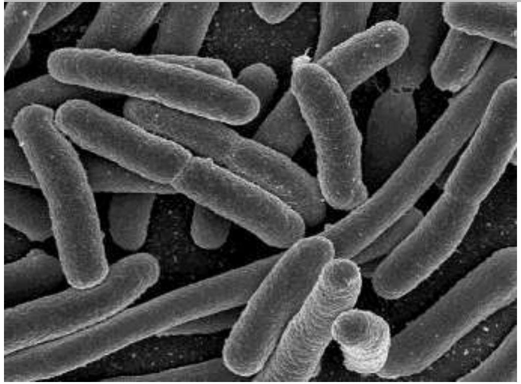
Harmful

Food spoilage

Diseases

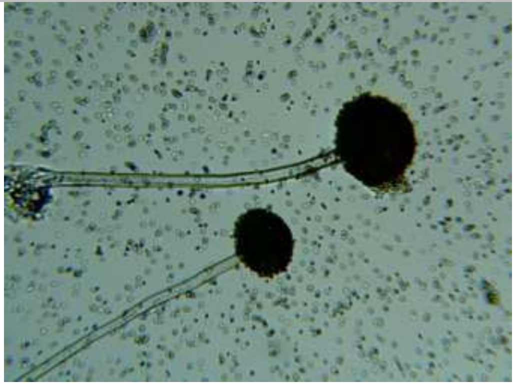
Bacterial
Viral
Fungal

Microbiology includes study of



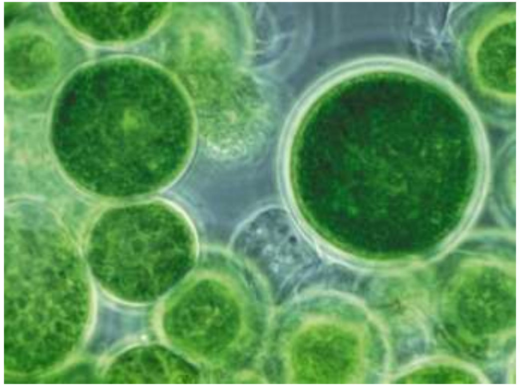
Bacteria

Viruses

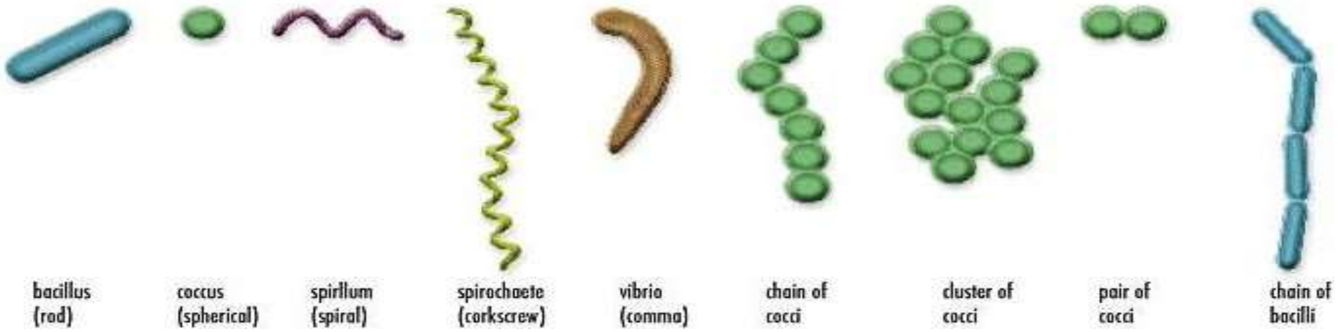


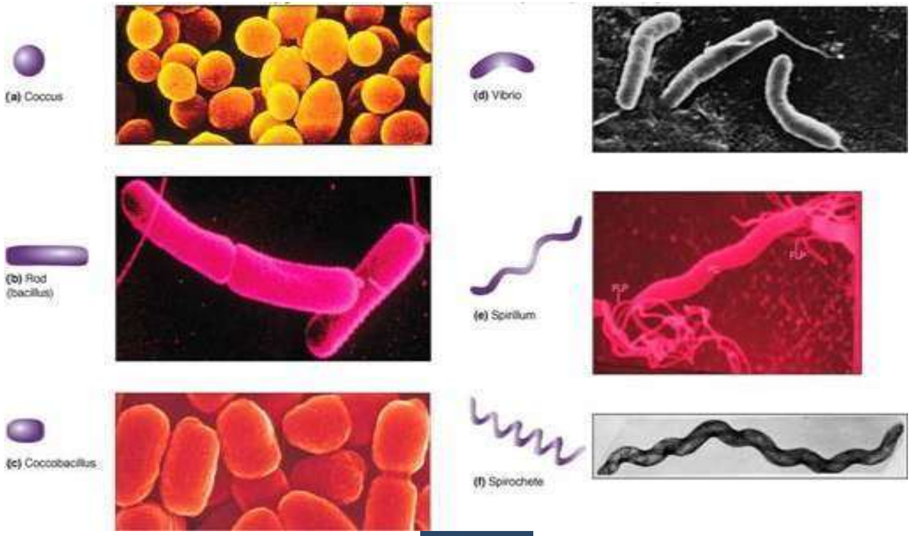
Fungi

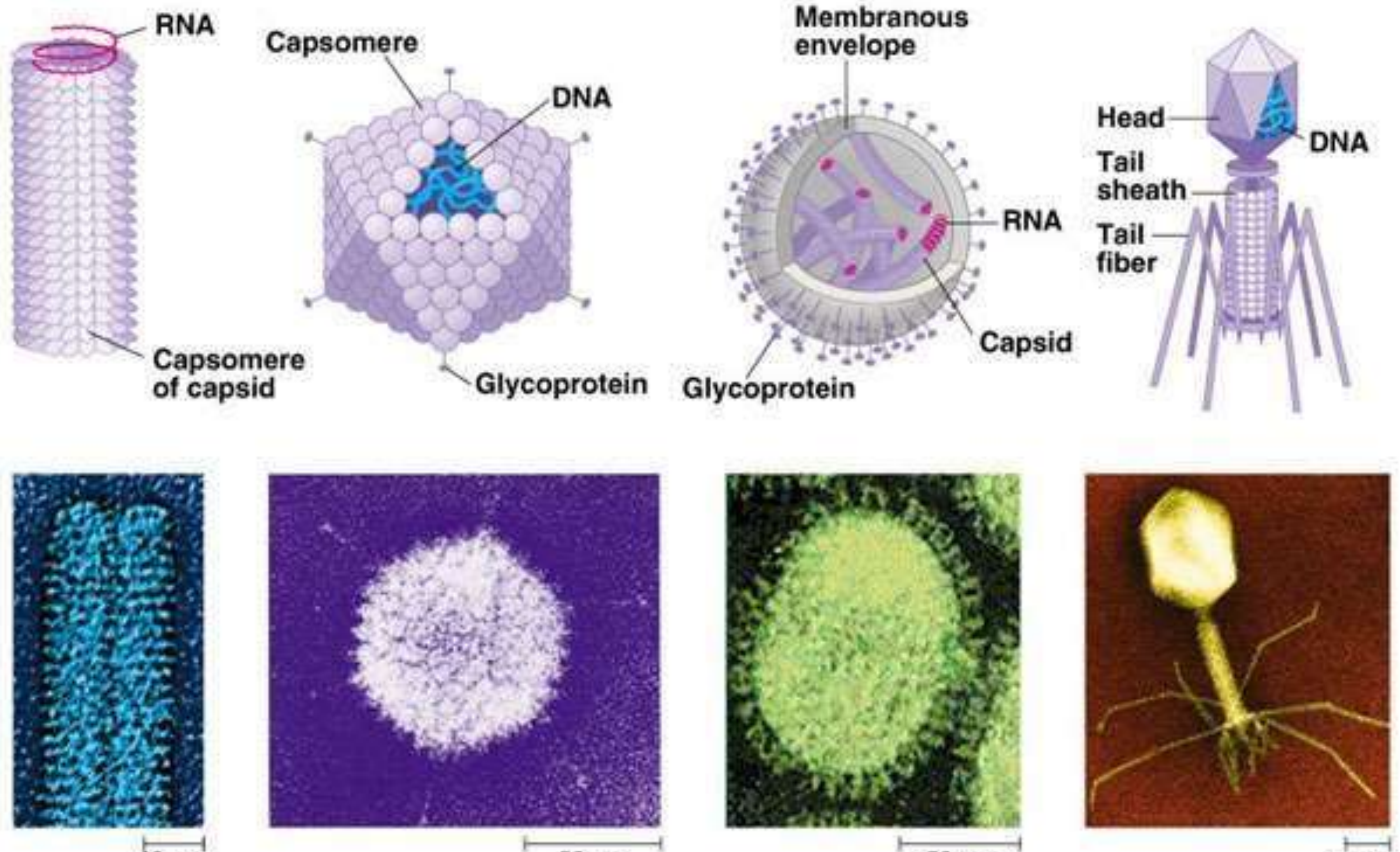
Protozoa



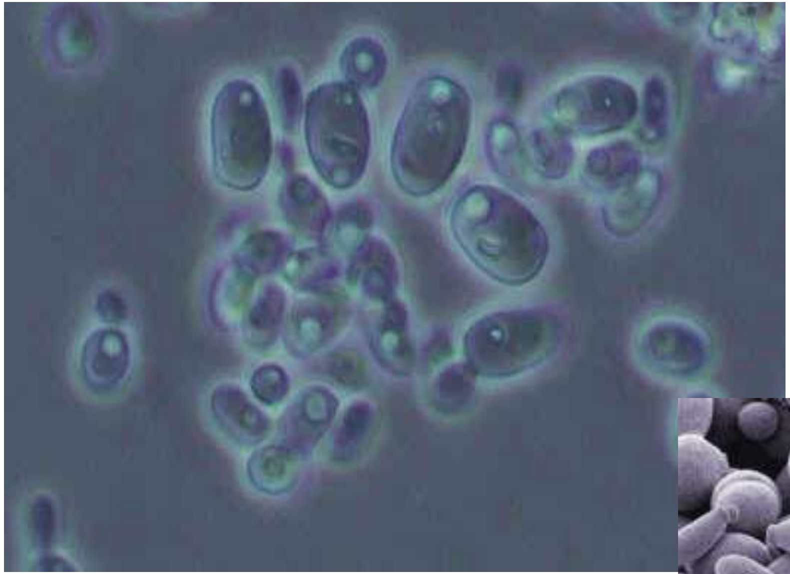
Algae

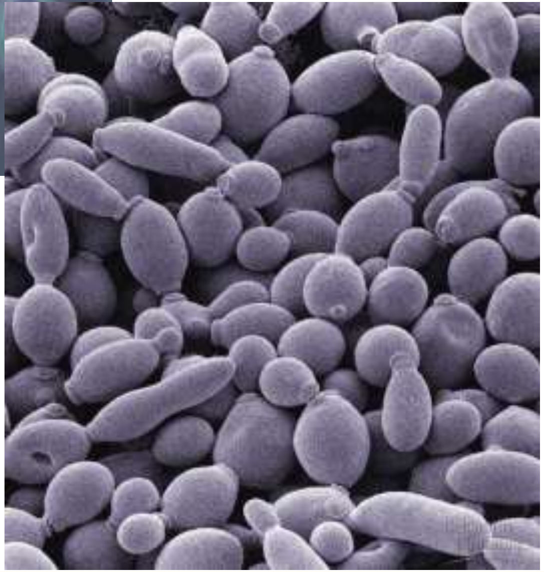

bacillus
(rod)
coccus
(spherical)
spirllum
(spiral)
spirochaete
(corkscrew)
vibrio
(comma)
chain of
cocci
cluster of
cocci
pair of
cocci
chain of
bacilli

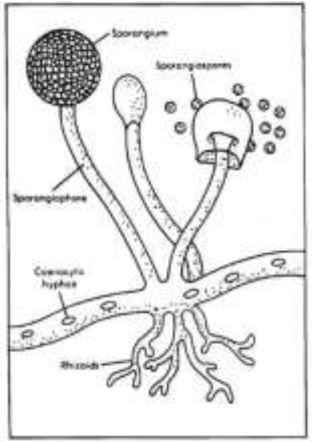

(a) Coccus
(b) Rod
(bacillus)
(c) Coccobacillus
(d) Vibrio
(e) Spirillum
(f) Spirochete



(a) Tobacco mosaic virus (b) Adenoviruses (c) Influenza viruses (d) Bacteriophage T4






Sporangium
Sporangiospores
Sporangiophore
Coenocytic hyphae
Rhizoids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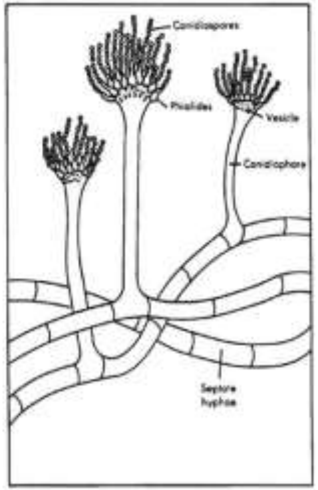
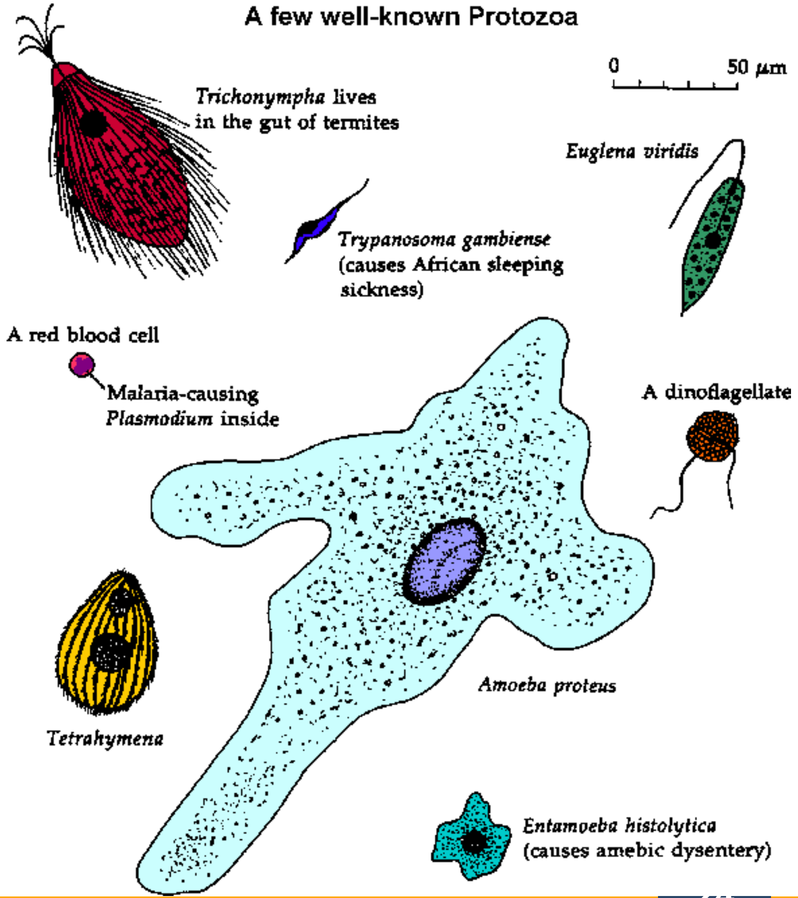
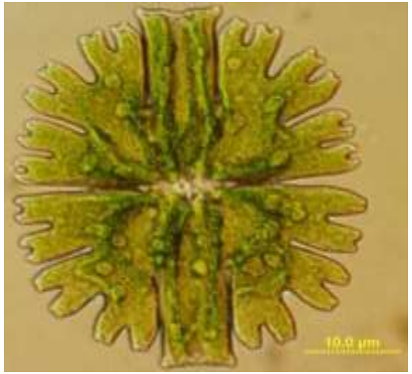
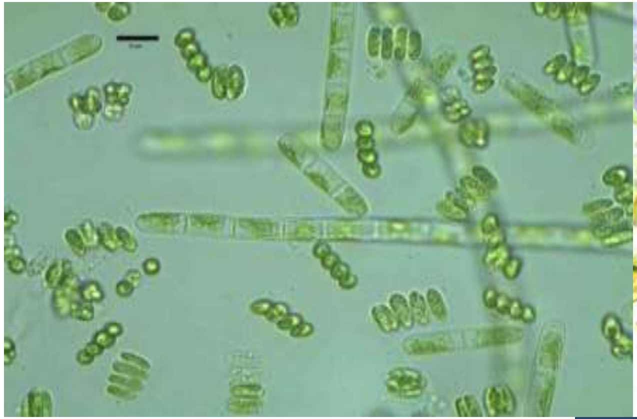
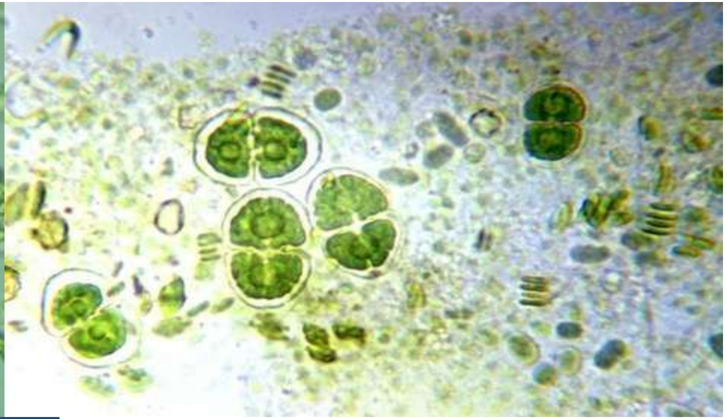

Conidiospores
Phialides
Vesicle
Conidiophore
Septate hyphae


A few well-known Protozoa
0 50 µm
Trichonympha lives in the gut of termites
Euglena viridis
Trypanosoma gambiense (causes African sleeping sickness)
A red blood cell
Malaria-causing Plasmodium inside
A dinoflagellate
Amoeba proteus
Tetrahymena
Entamoeba histolytica (causes amebic dysentery)

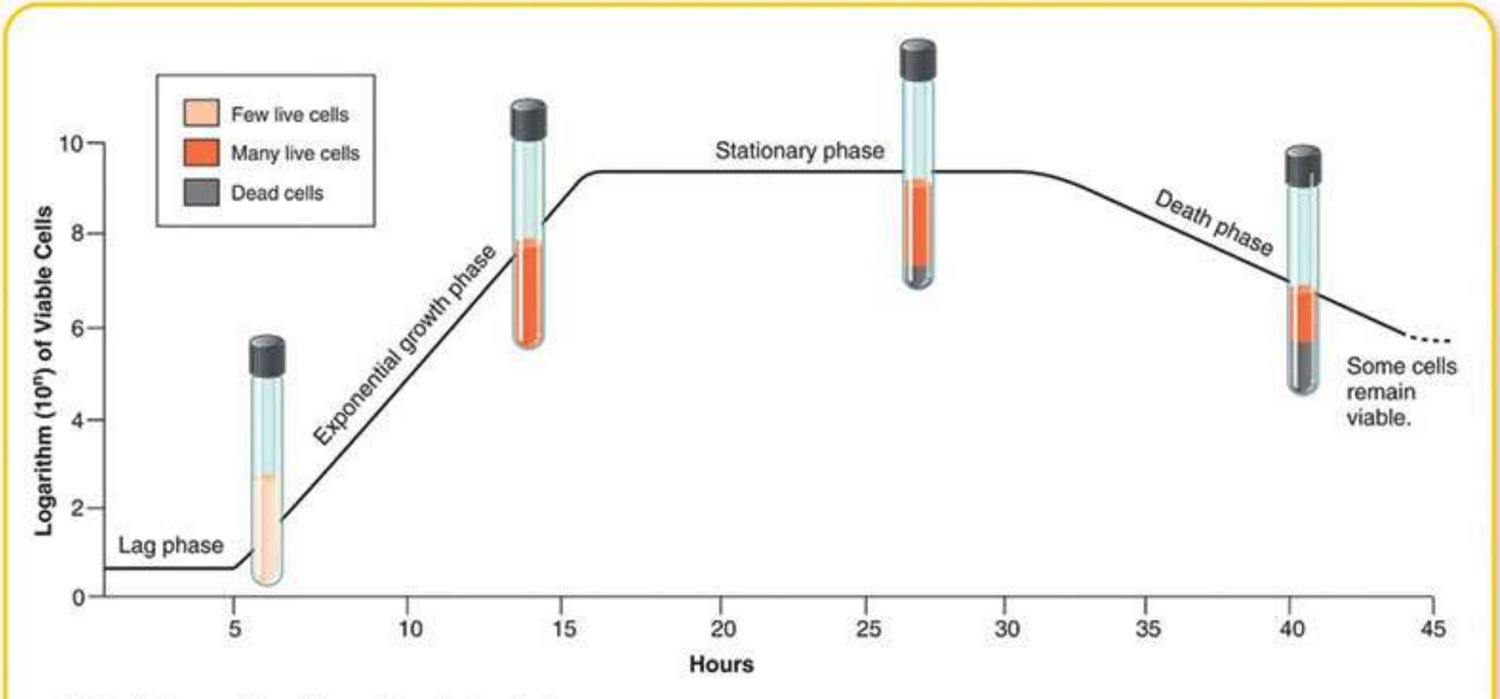

10.0 µm





Growth Kinetics

Growth is the fundamental, dynamic biological feature exhibited by the population of all species. If more number of individuals are added to the population, the population shows a positive growth.



Total cells in population, live and dead, at each phase.

Growth Kinetics

1. **Lag phase:** In the lag phase, the organisms do not increase significantly in number, but they are metabolically active-growing in size, synthesizing enzymes, and incorporating various molecules from the medium.

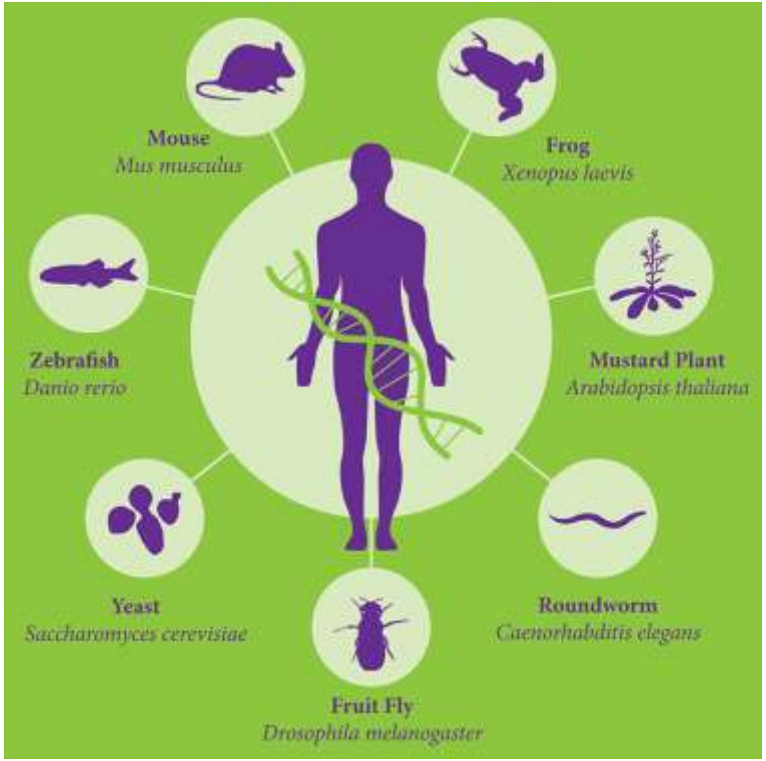
2. Log phase: Once organisms have adapted to a medium, population growth occurs at an exponential or logarithmic (log) rate. When the scale of the vertical axis is logarithmic, growth in this log phase appears on a graph as a straight diagonal line, which represents the size of the bacterial population. During the log phase, the organisms divide at their most rapid rate- a regular, genetically determined interval called the generation time. The population of organisms doubles in each generation time.

3. Stationary phase: When cell division decreases to the point that new cells are produced at the same rate as old cells die, the number of live cells stay constant. The culture is then in the stationary phase, represented by a horizontal straight line.

4. Decline (Death) phase: As conditions in the medium become less and less supportive of cell division, many cells lose their ability to divide, and thus the cells die. In this decline phase, or death phase, the number of live cells decreases at a logarithmic rate, as indicated by the straight, downward-sloping diagonal line.

Model Organisms:

- A model organism is a species that has been widely studied, usually because it is **easy to maintain and breed in a laboratory setting and has particular experimental advantages.**
- Model organisms are **non-human species** that are used in the laboratory to help scientists **understand biological processes.** They are usually organisms that are easy to maintain and breed in a laboratory setting.
- For example, they may have particularly robust embryos that are easily studied and manipulated in the lab, this is useful for scientists studying development, or they may occupy a pivotal position in the evolutionary tree, this is useful for scientists studying evolution.

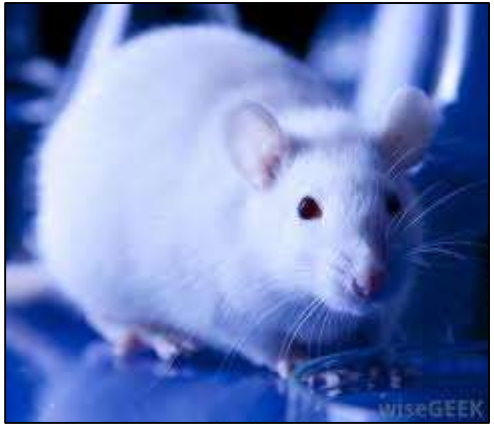


Model Organisms:

- In researching human disease, **model organisms allow for better understanding the disease process without the added risk of harming an actual human.**
- The species chosen will usually meet a determined taxonomic **equivalency to humans**, **so as to react to disease or its treatment in a way that resembles human physiology as needed.**

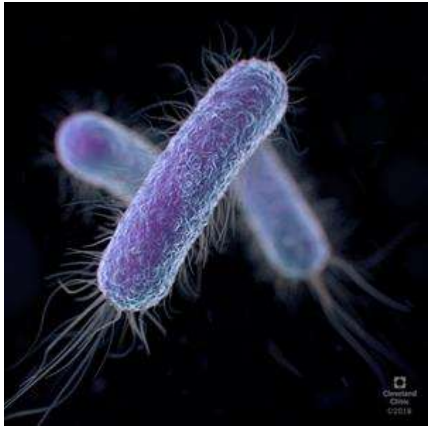
Model Organisms: Advantages

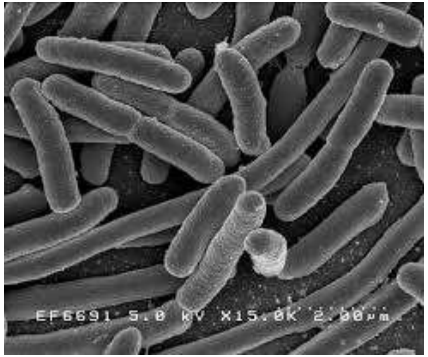
- Many model organisms **can breed in large numbers**. Some have a **very short generation time**, which is the time between being born and being able to reproduce, so several generations can be followed at once.
- **Mutants** allow scientists to study certain characteristics or diseases. These are model organisms that have undergone a change or mutation in their DNA that may result in a change in a certain characteristic.
- Some model organisms have **similar genes or similar-sized genomes** to **humans**. Model organisms can be used to create highly detailed genetic maps: Genetic maps are a visual representation of the location of different genes on a chromosome, a bit like a real map but one where the key landmarks are areas of interest in the genome. For example, areas of DNA that differ between individuals in the same species (SNPs) or genes. Therefore, model organisms are useful in genetic research.



Model Organisms: *Escherichia coli*

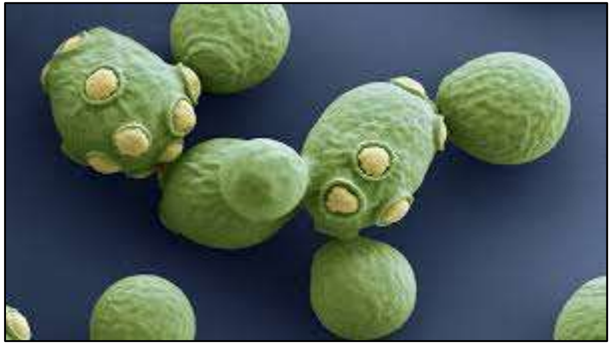
- E. coli is the **first choice for researchers to investigate numerous basic biological processes** which are essential for life and is the most extensively used organism in molecular genetics.
- The reason of widespread use of E. coli for study purpose is the **ease of its maintenance** and **breeding in a laboratory** environment plus its meticulous experimental advantages.
- As compared to other living organisms more is known about E. coli because of **its simple nutritional requirements**, **rapid growth rate** and most important it's well **established genetics**.
- Rate of cell division of *E. coli* is average of once in every 30 min, thus enabling quick environmental adaptation. This fast division rate of E. coli has helped in evolutionary experiments which are conducted in the laboratories.





Model Organisms: *Saccharomyces cerevisiae*

- Saccharomyces cerevisiae is a species of yeast. It is one of the most intensively studied eukaryotic model organisms in molecular and cell biology.
- It is the microorganism behind the most common type of fermentation. *S. cerevisiae* has developed as a model organism because it scores favorably on a number of these criteria. S. cerevisiae has been highly studied as a model organism to better **understand aging** for more than five decades and has contributed to the identification of more mammalian genes affecting aging than any other model organism.
- Some of the topics studied using yeast are **calorie restriction**, as well as in **genes and cellular pathways** involved in senescence.



Model Organisms: *Drosophila melanogaster*

- *Drosophila melanogaster* is a species of fly (the taxonomic order Diptera) in the family Drosophilidae.
- The species is known generally as the **common fruit fly** (though inaccurately) or **vinegar fly**.
- *D. melanogaster* is typically used in research because it can be readily reared in the laboratory, has only four pairs of chromosomes, breeds quickly, and lays many eggs.
- *D. melanogaster* remains **one of the most studied organisms** in biological research, particularly in genetics and developmental biology.
- All organisms use **common genetic** systems.

Model Organisms: *Drosophila melanogaster*

- Comprehending processes such as **transcription** and **replication** in fruit flies helps in understanding these processes in other eukaryotes, including humans.
- A study by National Human Genome Research Institute comparing the fruit fly and human genome estimated that about 60% of genes are conserved between the two species.
- About 75% of known human disease genes have a recognizable match in the genome of fruit flies, and 50% of fly protein sequences have mammalian homologs.
- An online database called **Homophila** is available to search for human disease gene homologues in flies and vice versa

Model Organisms: *Drosophila melanogaster*

- Drosophila is being used as a genetic model for several human diseases including the neurodegenerative disorders Parkinson's, Huntington's, spin cerebellar ataxia and Alzheimer's disease.
- The fly is also being used to study mechanisms underlying aging and oxidative stress, immunity, diabetes, and cancer, as well as drug abuse.

Model Organisms: *Caenorhabditis elegans (Roundworm)*

- Caenorhabditis elegans is a free-living, transparent nematode, about 1 mm in length, that lives in temperate soil environments.
- The name is a blend of the Greek caeno- (recent), rhabditis (rod-like) and Latin elegans (elegant). C. elegans is an unsegmented pseudo coelomate and **lacks respiratory** or **circulatory systems.**
- C. elegans is used as a model organism for the **investigation primarily of neural development** in animals. It is one of the simplest organisms with a nervous system.

Model Organisms: *Caenorhabditis elegans (Roundworm)*

- *C. elegans* has been a model organism for research into **ageing**; for example, the inhibition of an insulin-like growth factor signaling pathway has been shown **to increase adult lifespan threefold**; while **glucose feeding promotes oxidative stress** and reduce adult lifespan by a half.
- C. elegans has been instrumental to **identify the functions of genes** implicated in Alzheimer's disease, such as presenilin.

Model Organisms: *Arabidopsis thaliana*

- Botanists and biologists began to research *A. thaliana* in the early 1900s, and the first systematic description of mutants was done around 1945.
- *A. thaliana* is now widely used for **studying plant sciences**, including genetics, evolution, population genetics, and plant development.
- Although *A. thaliana* has little direct significance for agriculture, it has several traits that make it a useful model for understanding the genetic, cellular, and molecular biology of flowering plants

Model Organisms: *Mus musculus*

- Mus musculus is a small mammal of the order Rodentia, characteristically having a pointed snout, large rounded ears, and a long and hairy tail. It is one of the most abundant species of the genus Mus.
- Although a wild animal, the **house mouse** has benefited significantly from associating with human habitation to the point that truly wild populations are significantly less common than the semi-tame populations near human activity.
- The house mouse has been domesticated as the pet or fancy mouse, and as **the laboratory mouse**, which **is one of the most important model organisms** in biology and medicine.

Model Organisms: *Mus musculus*

- Mice are the most commonly used mammalian laboratory animal, due to their **relatively close relationship**, and **associated high homology**, with humans, their **ease in maintenance and handling**, and their **high rate of reproduction.**
- Laboratory mice typically belong to standardized inbred strains selected for the stability or clarity of specific harmful mutations. This allows research with laboratory mice to easily restrict genetic and biological variables, making them very useful model organisms in genetic and medicinal research.

Thank you…