Lecture 01

Nature & Scope of Biological Science

What is Biology? A brief history. Biology today. Group of organisms being studied. Approach taken to the study of organisms. New definition of Biology. Why study Biology?

Aspects of Science

Science has two aspects. It is both (1) a body of knowledge and (2) a method used for discovering new knowledge.

What is biology?

The word biology comes from the Greek words ***bios***, which means **life**, and ***logos***, which means **thought**. Thus, ***biology*** *is the science that deals with the study of life*.

A Brief History of Biology

Biology is a very old science. In fact, it probably began in prehistoric times.

Over thirty thousand years age, cave dwellers in France and Spain decorated the walls and ceilings of their caves with paintings of animals. These paintings show that the cave dwellers had closely observed the structure and behaviour of many animals.

When humans were mainly hunters of animals and gathers of edible plants, they studied biology at a simple level. They had to know the behaviour of their prey and, ofcourse, the behaviour of animals that might prey on them. They also had to observe the growing conditions required by the various plants as they collected them for food.

When human began an agricultural way of life about ten thousand years ago, they had to know much more about plants and animals. For example, they had to know when to collect seeds for their next year's crop, when to plants seeds, and how much moisture the various types pf plants needs. They also had to know what to feed their animals, how long the animals would live, and what might kill the animals. In a sense then, they were biologists because the studied living things. From such early beginnings came the science of biology.

Prehistoric humans had to rely on their senses alone to make observations. They had no laboratories, microscopes, dissecting kits, or other equipment.

What other living things is it like? While seeking answers to such questions, they probably discovered that the wide variety of living things had much in common, as well as many differences. They probably grouped similar living things and named each group. For example, they might have noted that all flying animals with feathers had much in common. They may have grouped them under one name such as birds. This process of grouping similar things is called ***classification***.

These early Biologists also would have observed other patterns in nature, such as regular migration of birds and life cycles of plants and animals.

As century passed, humans became more knowledgeable and curious. They began to ask more complex questions such as: ***What is it made of?*** and, ***How is it put together?***

Modern Biology
Modern biology began during the *17th century* when humans finally had the knowledge, skill, and equipment to seek answers to such questions. During that century **Robert Hooke** (1635-1703) and **Anton van Leeuwenhoek** (1632-1723) introduced a new tool, the microscope, to the scientific world. Another pioneer of modern biology was **William Harvey** (1578-1657), an English physician. He showed the importance in biological studies of well-designed experiments and careful observations. He traced the pattern of circulation of blood in humans, and showed that it travelled in one direction through the arteries and veins in a circular path.

The search for still more knowledge by curious scientists led them to ask even more complex question: ***What do the parts of a living thing do? How do the parts work?*** With the asking of such questions, biology truly came of age.

Biology Today
Modern biology is vast science. Over 1,500,000 different kinds or species of organisms have been identified and new ones are still being discovered. Biologists think that there may be over 2,000,000 different species on earth. They range in size and complexity from tiny bacteria to trees and humans. Because biology is such a large field, it is broken down into several subdivisions for easier study. These observations are formed according to the group of organisms being studied or the approach taken to the study of the organisms.

Group of Organisms Being Studied
Examples of some of the main fields of biology formed using this method of subdivision are:

Botany	The study of plants.
Zoology	The study of animals.
Microbiology	The study of microscopic organisms.
Bacteriology	The study of bacteria.
Virology	The study of viruses.
Mycology	The study of fungi.
Entomology	The study of insects.
Ornithology	The study of birds.

Approaches taken to the Study of organisms
Examples of some of the main fields of biology formed using this second method of subdivision are:

Taxonomy	The classification of organisms.
Morphology	The study of the external form and structure of organisms.
Anatomy	The study of the internal structure of organisms.
Physiology	The study of the function of organisms.
Cytology	The study of cells.
Ecology	The study of the relationship of organisms to their environment.
Genetics	The study of inheritance
Pathology	The study of diseases.

Unifying Themes of Biology

☐ Hierarchical organization of life
-- structural make up, from the smallest, simple to largest,complex
☐ Cell theory
-- all organisms are made of cells, central idea in all studies of biology
☐ Heredity
-- Biological information is inherited from parents in one generation by the offspring in the next.
☐ Evolution
-- the modification of populations over time
☐ Regulation
-- To survive and reproduce, all forms of life must regulate their internal, and sometimes external, environment.
☐ Structure and function
-- Correlations between the structure of a biological object, and its function.
☐ Environmental interactions
-- Individuals interact with other organisms of their own species and those of the greater community.
☐ Energy flow
-- Energy flows through a food chain, cycles through an ecosystem, or is converted to different forms within the cells of an organism.

A New Definition of Biology

Biology was first defined as the science that deals with the study of life. However, as we learn more, we see that biology involves many other things. It is also a study of all those things that affect life. Thus the following is a more accurate definition of biology:

Biology is the study of living things and the things that were once alive, together with the matter and energy that surround them.

Review Questions

1. State the two main aspects of every science.
2. Explain the origin of the word *Biology*.
3. Give a simple definition of biology.
4. State the modern definition of biology.
5. Name, with definition and example, five subdivisions of biology formed according to the group of organisms being studied.
6. Name, with definition and example, five subdivisions of biology formed according to the approach taken to the study of the organisms.

Lecture 02

Characteristics of Living Things

What is life? (1) The Need for Energy. (2) Movement. (3) Cellular Structure and Organisation. (4) Growth & Development. (5) Maintenance & repair. (6) Reproduction, (7) Response to stimuli. (8) Variation & Adaptation. (9) Metabolism.

What is Life?

What is life? What is the difference between a living and a nonliving thing? You would have no trouble deciding that a dog running down the street was alive; nor would you have any trouble deciding that a stone was nonliving. However, if you ask yourself whether a bean seed, an apple, or a potato is living or nonliving, you may have problems deciding on the answer. All these appear just as nonliving as a stone. Yet we know that all three can produce a living plant. Since it seems unlikely that a nonliving thing can produce a living plant, we can assume that the bean seed, apple, and potato are living. *What, then, are the characteristics of living things?*

Characteristics of Living Things

There are nine characteristics of living things.

1. The need for energy
2. Movement
3. Cellular structure and organization
4. Growth and development
5. Maintenance and repair
6. Reproduction
7. Response to stimuli
8. Variation and adaptation
9. Metabolism

1. The Need for Energy

All living things require a continuous supply of energy to support their more obvious characteristics such as movement, growth, and reproduction.

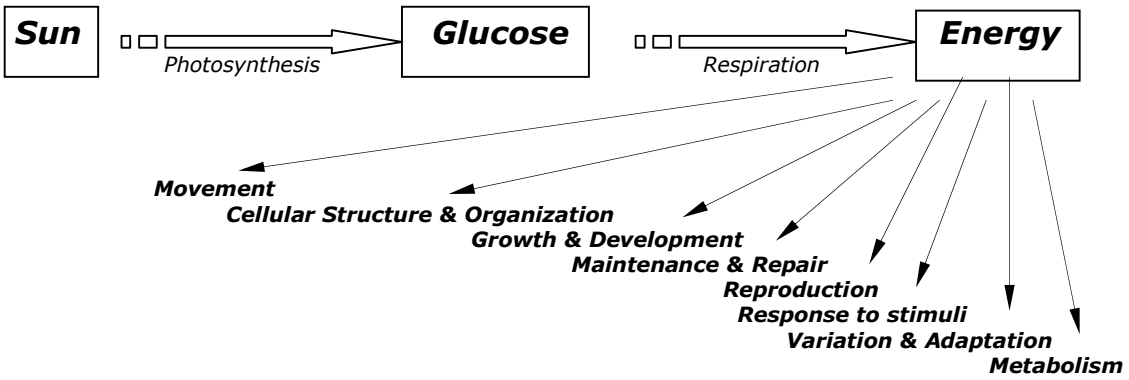


Figure: All living things have common characteristics. These characteristics are functions that require energy.

Almost all the energy used by living things comes originally from the sun (Figure). Green plants, through **photosynthesis**, store some of the sun's energy in compounds such as **glucose**. These plants, through **respiration**, then '*burn*' or

breakdown the glucose, releasing the energy needed to support their life processes. Animals get their supply of energy by eating the plants or by eating other animals that have eaten plants. By doing this, they obtain glucose and other compounds which they too, break down through **respiration** to release energy to support their life processes.

2. Movement

Movement

One of the most obvious characteristics of living things is movement. Most **animals** show obvious signs of movement when they are alive.

Although movement in **plants** is not as obvious, it does occur. This movement can be very slow, such as (1) the opening of buds on a tree or (2) the turning of leaves of a plant toward the sun. In contrast, (3) the tiny sundew of northern bogs and (4) the Venus flytrap of Carolinian bogs show much more rapid motion. One of the most interesting examples of motion in plants is shown by (5) the *Mimosa pudica*, commonly called the Sensitive Plant. If this plant is touched, its leaves quickly fold up.

Many animals, plants, and microscopic organisms show few or no outward signs of movement. Yet under the microscope, you can see that the cell contents of these organisms are in continuous motion. This proves that in one way or another, all living things show movement.

Locomotion

Some organisms show a special type of movement called ***locomotion***. *Locomotion is the movement of an organism from one place to another*. Most animals can carry out locomotion but very few plants can. Remember that both movement and locomotion, in a biological sense, must be initiated or caused by the organism itself. Locomotion does not occur when the wind blows a plant from one place to another, nor does movement occur when the wind moves the branches of a tree.

3. Cellular Structure and Organization

All living things are made up of **cells**. Some have only one cell; others have millions of cells. Some cells are very simple and others are very complex. However, from bacteria and amoebas to trees and humans, the cell is the basic unit in which substance are organized to produce a living thing.

Protoplasm

Living cells contain a complex mixture of substances that is called ***protoplasm***. This mixture is found only in living cells. The protoplasm itself, however, is not alive. None of the materials of which protoplasm is made — carbohydrates, fats, proteins, waters, and other compounds — are alive. Yet, living cells have the ability to organize all these materials into what biologists call a ***living condition***. Protoplasm differs from one kind of organism to another and even from one individual to another of the same kind. It even differs from one part of an individual to another part of the same individual. In fact, the composition, or makeup, of any particular sample of protoplasm is always changing.

Organism
Living things have the ability to organize materials into protoplasm and to organize protoplasm and other substances into cells. Living things are therefore called ***organisms*** *because of this ability to organize substances.*

4. Growth and Development

Growth
All living things **grow** at some time during their lives. The total growth may be very small, as in the case of a bacterium or an amoeba. Total growth can be quite extensive, as in the case of a whale or a large tree. Yet, whether great or small, growth is a characteristic of all living things.

However, many **nonliving things** can also grow. For example, crystals of sugar, salt, and bluestone can be made to grow larger. You probably have seen an icicle grow. *How, then, can we say that growth is a characteristic of living thing? What kind of growth are we referring to?*

The crystals and the icicle grow larger by adding more material of the same kind to their surfaces. The **growth of living things** is quite different from this. A dog does not grow by the collection of more dogs on its surface; nor does a mango plant grow by the collection of more mango plants on its surface. Yet, neither of these organisms grows simply by taking in food. They must organize the food, along with water, minerals, and other chemicals, into the complex materials that make up protoplasm and the other parts of living cells.

Living things grow, not by adding more of their own material to their surfaces, but by organizing materials that they take in to form their own special kind of protoplasm.

Development
If you plant a bean seed, it will become a bean plant. It never becomes a potato plant or a tree. It becomes a unique living thing with specialized parts that make it different from other living things. *The series of changes that take place as an organism grows toward its final form is called* ***development***. All living things undergo development.

5. Maintenance and Repair

Most living things live long after growth appears to have stopped. Yet, in one sense, they continue to grow as long as they are alive. They may not grow any larger but they must continually **maintain and repair** the materials of which they are made.

For example:
1) Skin cells on your body wear away and must be replaced by new ones. A cut on your finger heals because new tissues are produced to cover the cut.

2) Some organisms, such as the salamander, house lizard and crayfish, can even grow new limbs or tail to replace lost ones by recognizing old, and adding new, material.

Living things use great deal of energy in the maintenance and repair of worn-out and damaged parts. This is a characteristic of all living things.

6. Reproduction

Only living things can produce offspring similar to themselves. Shrimps lay eggs that hatch and develop into shrimps; bluebirds lay eggs that eventually produce bluebirds; horse give birth to horses; apple seeds grow into apple plants; and mango seeds become mango trees.

*It is a basic law of biology that only **life can produce life** and **like produces like**. Reproduction is the process whereby all living organisms produce offspring*.

Organisms must be able to reproduce themselves because they have a limited life span. After most organisms are formed, they go through a period of rapid growth. They eventually reach a stage called maturity at which growth in size usually ceases but maintenance and repair may continue. They then enter a period of decline in which maintenance and repair of worn-out and damage materials are no longer fast enough to keep the organisms in a stable state. Finally death occurs.

Life span

Life spans vary considerably from one type of organism to another. Some **insects** live only a few weeks. **A person** in Western world can expect to live, on the average, about seventy years. A **horse** lives about thirty years. **Some trees** live for a few decades and *others* for hundreds of years. Some **redwood trees** in California have lived for several thousand years. Some simple organisms such as **bacteria and amoebas** appear to have an indefinite life span. In a sense, they live forever, because they reproduce by splitting in two. The offspring repeat this process. Clearly such organisms never die of old age!

Organisms use a great deal of energy in the reproduction of offspring. This also is a characteristic of all living things.

7. Response to Stimuli

Irritability

All living things are able to respond to certain ***stimuli*** or change in their environment (surroundings). A **dog** comes when you whistle. A **fly** moves when you try to swat it. A ***Mimosa*** (Sensitive) plant folds its leaves in response to darkness, touch, and heat. A **plant** in a window turns its leaves toward the light. **Earthworms** seek out moist soil containing decaying vegetation. In all these examples a ***stimulus***—*sound, touch, heat, light, moisture*—causes a response by a living thing.

*A living thing's response to a stimulus is called **irritability***.

Irritability is valuable to **animals** in many ways. It helps them obtain food and avoid predators. It is most highly developed in those animals that have **nervous systems** and keen **sense organs** such as eyes, nose, and ears.

Plants usually respond slowly to *stimuli* because they lack sense organs, muscles, and other parts needed for a quick response. However, they usually respond to **light** by turning their leaves towards it. They also respond to **gravity** by sending roots downward into the soil. Many homeowners have discovered, to their dismay that Poplar and Willow trees often respond to the presence of **water** around a home by clogging the water trains with roots.

Even **single-celled organisms** such as amoebas show *irritability*. Such organisms respond to *touch*, *light*, *heat*, and *other environmental stimuli*.

Coordination
Response to stimuli must be **coordinated** if they are to be effective. Even simple organisms have many parts and each part must do the right thing at the right time if the proper response is to be carried out. For example, when you call a **dog** to supper, stimuli will be received by one or more of the *eyes*, *ears*, and *nose*. The responses to these stimuli must be coordinated within the dog before it can respond properly. Some muscles must contract; others must relax; digestive juices must be secreted. A system of nerves and a system of chemical regulators called **hormones** coordinates these responses in a dog and many other animals. In **plants**, only hormones are involved in the coordination of responses.

Behaviour
Organisms respond to stimuli by changing their relationship to it. For example, a **dog** usually comes when you whistle. It changes its location in response to the stimulus. *Such responses, which often occur in definite pattern, are called **behaviour***. Remember that behaviour must begin with the organism. A **ball rolling** down a hill is not showing behaviour. It is simply being pulled along by the force of gravity. However, a **dog** that responds to a whistle creates a change in its relationship to its environment. Your whistle does not pull the dog to you. Organisms use a considerable amount of energy as they respond to stimuli within their environments.

8. Variation and Adaptation

Variation
*Change occurs as a result of a characteristic called **variation***.

Offspring always differ in some ways from one another and from their parents. These differences are called *variations*.

- Most variations do not affect an organism's chances of survival. For example, the fact that your hair is a different colour from your parents will not likely affect your chances of survival.

- However, now and then a variation occurs that does give an organism a better chance of surviving in a changing environment. Suppose that the climate of an area is changing and deeper snow is produced each winter. Clearly a variation that produced longer legs in a deer would increase that deer's chances of surviving in that area. If this variation is passed on to the offspring of that deer, they, also, would have an increased chance of survival. Gradually the only deer of that type to be found in the deep snow area may be the long-legged types. The others would have moved away or died.

Adaptation
*The process by which a certain type of organisms becomes better suited to survive in its environment is called **adaptation***.

Keep in mind that organisms do not change in order to survive in a changing environment. The deer in our example did not grow long legs because they needed them to survive in the deep snow. *Organisms do not change to survive; they survive because they change.*

9. Metabolism

Metabolism *is the exchange of matter and energy between an organism and its environment, and the changes that occur in this matter and energy when they are within the organism*.

In effect, metabolism is the sum of all the processes occurring in an organism.

- It includes taking in food, or **ingestion**, as well as taking in water and air.
- It also includes all the changes in food materials that occur within organisms during **digestion**.
- It includes all changes that occur as the products of digestion are **assimilated**, or put together, during growth, maintenance, and repair.
- Finally, metabolism includes the release of energy through **respiration**.
- Finally, it includes the elimination of by-products through **excretion**.

Metabolism has two distinct phases, anabolism and catabolism.

- ***Anabolism*** *is a constructive or building-up phase; it includes assimilation, or building of protoplasm from simple compounds and elements that were obtained as a result of ingestion and digestion*. It also includes the process of photosynthesis.

- ***Catabolism*** *is a destructive or breaking-down phase; it involves the release of energy by the breakdown of food materials through respiration*.

Review Questions

1. Why do all living things require energy?
2. Show that energy of all living things originally come from the sun.
3. What are the nine characteristics of living organisms?
4. Describe with examples of movement in plants.
5. What is locomotion?
6. What is protoplasm?
7. Why is a living called an organism?
8. Describe the differences between the growth of a living and a nonliving thing.
9. What is development?
10. What is the difference between development and growth?
11. How do maintenance and repair differ from growth?
12. What is reproduction?
13. Why is reproduction necessary?
14. What is stimulus?
15. What is irritability?
16. Describe an example of the importance of irritability to an animal.
17. Describe an example of the importance of irritability to a plant.
18. What is behaviour? Describe an example of behaviour.
19. What are variations?
20. What is adaptation?
21. What is metabolism?
22. Name and define the two phases of metabolism.
23. Name and briefly describe five processes that can occur during metabolism?

Lecture 03

Classification of Living Things

Introduction; What is classification? Early biological classification. Modern biological classification. The contribution of Linnaeus. The basis of classification. Binomial nomenclature. The genus and species concept. Why use scientific names? Modern basis of classification. Selecting a classification system, Two-kingdom system, Three, four, or five kingdom system, Phylogenetic system.

Introduction

Biologists believe that there may be over **two million** (2,000,000) different kinds of organisms. Already over **1.5 million** (1,500,000) different kinds have been identified and new ones are still being discovered. One biologist estimates that for each kind of organism now alive, another **400 kinds** once lived but have since become extinct. Therefore, as many as one billion (1,000,000,000) different kinds of living things may have existed on the earth at one time or another.

How ca we keep track of such a bewildering number of organisms? How can we even name the organisms now alive when no known language has two million words in it? Biologists have answers to these questions.

What is Classification?

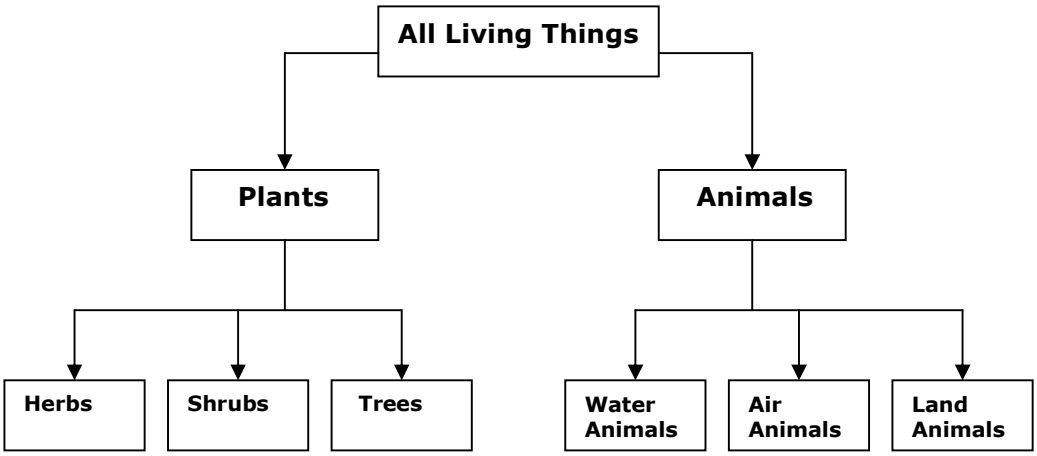
Whenever we work with a large number and variety of things, we usually sort them into groups. Each group contains those things that are similar to one another. We may then separate each of those groups into smaller groups that are even more alike.

The grouping of similar things for a specific purpose is called ***classification***. Although it may be instinctive for human to classify things, there are also practical reasons for doing this. For example, a **supermarket manager** classifies the foods in his/her store by storing all the cereals together, all the meats together, all the cookies together, and so on. **Stamp collectors** classify their stamps. They place all the Canadian stamps in one page and all the American stamps in another. The words in a **dictionary** are classified by alphabetical listings. Clearly, we classify things to make it easier to keep track of what we have, and to find particular items.

Early Biological Classification

Biologists have long recognized the need to classify living things. In fact, humans have been classifying living things for thousands of years. The earliest humans probably classified organisms as plants and animals. They may have further classified plants as edible or poisonous, and the animals as harmful or harmless. However, it was 300 BC before the first serious attempt was made to classify all the organisms known. This attempt was made by the Greek philosopher and scientist, **Aristotle** and his students.

Aristotle's Classification System
Since only about 1000 kinds of organisms were known at that time, a very simple classification scheme could be used. Aristotle and his students first classified the organisms as plant or animal. They then classified the animals according to where they lived. This resulted in three groupings: **air animals**, **water animals**, and **land animals**. They classified the plants according to the structure of stems. Those with soft stems were called **herbs**; those with a single woody stem were called **trees**; and those with many small woody stems were called **shrubs**.



Aristotle's classification system survived for almost two thousand years. However, by the beginning of the 18th century, over 10,000 kinds of organisms were known and Aristotle's system was unable to classify them all. Many of newly discovered organisms would not fit into any category of Aristotle's simple system. A new system was obviously needed.

Modern Biological Classification

Taxonomy
Taxonomy is the science that deals with the classification of organisms.

The Contribution of Carolus Linnaeus
Carolus Linnaeus, a Swedish botanist, developed a simple classification system that forms the basis of our modern method of classification. At the start of the 18th century about **10,000** kinds of organisms were known. By the end of that century over **70,000** kinds were known. Linnaeus tried to develop a classification system for this large number of organisms. By **1753** his system was well developed and modern taxonomy began.

The Basis for Linnaeus Classification
*Biologists use the word **diversity** to mean differences, or the number of kinds of living things*.

There seed to be so many kinds of living things and they seem to be so different from one another. Yet, if we study them closely, we can see many likenesses. For example, at first glance lions, horses, humans, and mice seem to have little in

common. A closer look however, shows that all have hair, a distinct head, four limbs, two ears, and warm blood. That is, they have similar **structural features**.

Linnaeus decided to use structural features as the basis for his classification system. Therefore, he grouped organisms according to their structural similarities. These organisms with very similar structural features were considered to be the same **species**. Thus all modern-day humans belong to one species, all house cats belong to one species, and all sugar maple trees belong to one species.

Binomial Nomenclature
Once Linnaeus had decided on a basis for classifying organisms, he then developed a system for naming them. His system is quite simple. He gave each species a name that consists of two words. This system is called **binomial nomenclature**. He used Latin words for these names because all scientists wrote in Latin in time of Linnaeus. Thus, the human is *Homo sapiens*, and the domestic (house) cat is ***Felis domesticus***. The first word of each name is called the **genus** and the second word is called the **species**. The genus begins with a capital letter and the species does not. The genus and species are either printed in italics or underlined.

The Genus Concept
*A **genus** (plural genera) groups species that are similar*. For example, maple trees belong to the genus *Acer*. Thus sugar maple (***Acer saccharum***), silver maple (***Acer saccharinum***), and red maple (***Acer rubrum***) belong to the same genus ***Acer***. Their leaves are similar and other features are similar but not identical. Every genus has characteristics that make it stand out clearly from other living things.

The Species Concept
*Linnaeus grouped as a **species** those organisms that he felt were very similar in structural features*. In simple terms, a single species is a distinct kind of organism, with a characteristic shape, size, behaviour, and habitat that remains constant from year to year.

*A **species** (plural also species) is defined as a group of individuals that are alike in many ways and interbreed under natural conditions to produce fertile offspring (children)*.

Potato (***Solanum tuberosum***) and the eggplant (***Solanum melongena***) belong to the same genus because they are similar in many ways. However, they belong to two different species because they are not identical and they have reproductive barrier, that is, they cannot mate (cross or breed) with one another to produce fertile offspring. The members within a species can mate or cross. Thus all varieties of potatoes are in the species because they can interbreed to produce fertile offspring.

Why Use Scientific Names?
One reason for using Latin scientific name instead of common names is that common names can be confusing or misleading. For example ***Felis concolor*** is called a cougar, mountain lion, puma, panther, painter, and many names. The common name for a domestic cow is "**la vache**" in French, '**die Kuh**" in German, "**la vaca**" in Spanish, and "**garoo**" in Bengali. However, in all languages the scientific name is the same, and there is no confusion if we call the cow ***Bos taurus***.

The Main Classification Groups (Taxa)

There are seven main ***taxa*** or classification groups. This system of classification can be compared to a tree. Many leaves (***species***) are on a tiny twig (***genus***). Several tiny twigis (genera) are on a larger twig (***family***). Several larger twigs (families) are on a little branch (***order***). Some little branches (orders) are on a larger branch (***class***). Some larger branches (classes) are on a main limb of the tree (***phylum***). The few main limbs (phyla) make up the whole tree (***kingdom***).

1. Species: *Species (plural also species) is a group of individuals that are alike in many ways and interbreed under natural conditions to produce fertile offspring (children)*.

2. Genus: *Genus (plural genera) is a group of species that are closely similar in structure and evolutionary origin.*

3. Family: Family *is a group of similar kinds of genera. That is, similar genera are grouped to form a taxon called Family.*

4. Order: *Similar families are grouped to form a taxon called order*.

5. Class: *Similar orders are grouped to form a taxon called class.*

6. Phylum or Division: *Similar classes are grouped to form a taxon called phylum or* ***division***. Zoologists favour phylum and botanists favour division.

7. Kingdom: *All the phyla or divisions that contain animals are grouped in the kingdom Animalia, and all the phyla or divisions that contain plants are grouped in the kingdom Plantae*.

Classification of Some Organisms

Taxon	***Human***	***Gorilla***	***Dog***	***Cat***
Kingdom	Animalia	Animalia	Animalia	Animalia
Phylum or Division	Chordata	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Mammalia	Mammalia
Order	Primates	Primates	Carnivora	Carnivora
Family	Homonidae	Pongigae	Canidae	Felidae
Genus	*Homo*	*Gorilla*	*Canis*	*Felis*
Species	*sapiens*	*gorilla*	*familiaris*	*domesticus*

Modern Basis for Classification

Homologous Structure

Carolus Linnaeus used structural features as the basis for his classification system. He grouped organisms according to their structural similarities. Today, taxonomists still use structural similarities as a basis for classification. They look for homologous structures just as Linneaus did.

Homologous structures *are structures that show the same basic pattern, the same general relationship to other parts, and the same pattern of development*.

However, they need not have the same function. For example, the **human arm**, the **whale flipper**, and the **bat's wing**, all these appendages are homologous structures that show the same basic pattern. Also, all three appendages are found in the same part of the body. Finally, the bones in all three appendages develop in similar ways. Although their functions are different, they are homologous structures.

Similar Biochemistry
Biochemistry is the study of the chemical compounds formed by living things. Many biologists believe that closely related organisms form similar chemical compounds in their body. They use this belief to help classify organisms. For example, the horseshoe crab was, at one time, classified as a close relative of the true crab. However, chemical analysis showed that its blood was more like spider's blood than crab's blood. Thus, the horseshoe crab is now classified as a close relative of spiders.

Genetic Similarity
Most biologists agree that ***genetic similarity*** *is the best evidence that organisms are closely related*. Every organism makes a special compound called DNA that bears hereditary characters. Thus it seems reasonable to assume that *the greater the similarity of DNA among organisms, the more closely they may be related*.

Selecting a Classification System
Some biologists feel that two kingdom, Plantae and Animalia, are enough to classify all living things. Others prefer three kingdoms; still others use four, and some use five kingdoms.

A Two-Kingdom System of Classification
Carolus Linnaeus introduced this system of classification in 1753. This is the oldest and perhaps still the most widely used system of classification. It groups all organisms into two kingdoms, (1) **Plantae**, which includes bacteria, algae, fungi and higher plants, and (2) **Animalia**, which includes protozoa and higher animals. That is, all living things are assumed to be either plants or animals.

This system works well for most organisms. **Problems** arise, however, with some of the one-celled organisms, particularly the **flagellates**. Because these organisms have flagella and show locomotion (movement from one place to another) they seem to be animals. However, they also contain chlorophyll and make their own food by photosynthesis. In this respect they are like plants. For many years botanists have claimed that the flagellates were plants and zoologists have claimed that they were animals.

A Three-Kingdom System of Classification
Ernst H Haeckel introduced this system of classification in **1866**. The problem of the flagellates is handled by a 3-kingdom system of classification. This system still has the kingdoms (1) **Plantae** and (2) **Animalia**, however, it has a third kingdom, (3) **Protista**. The kingdom Protista contains all microorganisms, including the bacteria, blue-green algae, protozoa, unicellular algae (*eg*., flagellales), and microscopic fungi.

This system was recognized by many biologists during the first half of the 20th century and is still very popular. Yet it also has some **problems**. For example, the bacteria are very different from the other protists like flagellates, protozoa and one-

celled algae. Their cells lack true nuclei (prokaryotic in nature) unlike all other protists, which have true nuclei (eukaryotic in nature).

A Four-Kingdom System of Classification

To solve the problem with prokayotic and eukaryotic microorganisms in classification some biologists proposed a fourth kingdom, **Monera**, which contains only the bacteria or prokarytic microorganisms. Therefore, the four kingdoms are (1) **Plantae**, (2) **Animalia**, (3) **Protista** which includes only the eukayotic microorgaisms, and (4) **Monera** which includes prokaryotic microorganisms.

Still there have some major **problems** in 4-kingdom system. Some biologists took a close look at the fungi. They decided that the fungi were so different from the other organisms in kingdom Plantae that they should also be moved to a kingdom of their own. Fungi do not have chlorophyll and therefore cannot carry out photosynthesis; therefore, they are very different from plants.

A Five-Kingdom System of Classification

Robert H Whittaker introduced this system of classification in **1969**. In this system fungi were separated from the kingdom Plantae as they are quite different from the usual plants. Therefore, the five kingdoms are (1) **Plantae**, (2) **Animalia**, (3) **Fungi** (4) **Protista**, and (5) **Monera**.

Even the 5-kingdom system is not without **problems**. Organisms that have traditionally been called algae are now spread over three kingdoms. The blue-green algae are in kingdom Monera, unicellular algae are in kingdom Protista, and multicellular algae in kingdom Plantae. Already some biologists think that blue-green algae are not algae at all, but are simply bacteria. Remember, no classification system is perferct. No classification system will remain unchanged.

Phylogenetic System of Classification

Carl R Woese introduced a completely new approach in classification of organisms in 1977 that is based on evolutionary (phylogenetic) relationship among organisms. While at the University of Illinois, Woese turned his attention toward determining the origins of life on earth. He meticulously analysed ribosomal ribonucleic acid (rRNA), genetic molecules that coordinate part of protein production. Because rRNA shows only slight variation from one generation to the next, it is an excellent tool for revealing the evolutionary, or family, relationships among organisms. Woese spent nearly a decade analysing the rRNA of various types of bacteria and arranging them into a microbial evolutionary tree. Use this concept all organisms are now classified into three kingdoms. They are (1) **Archaea**, (2) **Bacteria**, and (3) **Eukarya**.

Summary of Various Classification Systems

Classification	*System Kingdom*	*Organisms Included*
2-Kingdom System *Carolus Linnaeus, 1753*	(1) Plantae	Bacteria, Cyanobacteria, Unicellular algae, Multicellular algae, Fungi & Higher plants
	(2) Animalia	Protozoa & Higher animals
3-Kingdom System *Ernst H Haeckel, 1866*	(1) Plantae	Multicellular algae, Fungi & Higher plants
	(2) Animalia	Higher animals
	(3) Protista	All microorganisms: Bacteria, Cyanobacteria, Unicellular algae, & Protozoa
4-Kingdom System	(1) Plantae	Multicellular algae, Fungi & Higher plants
	(2) Animalia	Higher animals
	(3) Protista	Eukaryotic microorganisms: Unicellular algae & Protozoa
	(4) Monera	Prokaryotic microorganisms: Bacteria, & Cyanobacteria
5-Kingdom System *Robert H Whittaker, 1959*	(1) Plantae	Multicellular algae & Higher plants
	(2) Animalia	Higher animals
	(3) Fungi	All fungi: Yeasts & Molds
	(4) Protista	Eukaryotic microorganisms: Unicellular algae & Protozoa
	(5) Monera	Prokaryotic microorganisms: Bacteria, & Cyanobacteria
Phylogenetic System *Carl R Woese, 1977*	(1) Archaea	Archaebacteria
	(2) Bacteria	Bacteria
	(3) Eukarya	Eukaryotic organisms: Algae, Fungi, Higher plants, Protozoa & Higher animals

Review Questions

1. What is classification? Give two reasons why human classify things.
2. Describe Aristotle's classification system for living things.
3. What is taxonomy?
4. What did Linnaeus use as the basis for his classification system?
5. What is binomial nomenclature? Give two examples.
6. What is a genus?
7. What is a species according to Linnaeus. What is the modern definition of species?
8. Why is it important that biologists in all countries use scientific names (binomial nomenclature) for organisms?
9. List, in order, the seven main taxa (classification groups) with example of each group, starting at kingdom.
10. Name the three modern bases for classification.
11. Why do biologists feel that the presence of homologous structures may be good evidence that organisms are closely related?
12. Describe, with an example, similar biochemistry in classification of organisms.
13. Describe the two main things a classification system should do.
14. Who proposed the 2-kingdom system of classification and what kingdoms are used in this system? Name the organisms belong to each kingdom.
15. What major disadvantage does 2-kingdon system have?
16. Who introduced 3-kingdom system of classification?
17. Name the kingdoms used in a 3-kigdom system of classification. Name the organisms belong to each kingdom.
18. What problem of the 2-kingdom system is solved by adding a third kingdom and what problems still remained in 3-kingdom system?
19. Who introduced 5-kingdom system of classification?
20. Name the kingdoms used in a 5-kingdom system of classification. Name the organisms belong to each kingdom.
21. What problems of the 3-kingdom system are solved by adding the fourth and the fifth kingdoms, Fungi and Monera?
22. Who introduced phylogenetic system of classification?
23. What is basis of the phylogentic classification?
24. What are major phylogentic groups?