Introduction to Biology

SYNOPSIS

This chapter will cover the following topics

1. Importance of biology as an integral part of other field of Science like Mathematics, Physics and Chemistry.
2. Study the fundamental differences between science and engineering by comparison between eye and camera, bird flying and aircraft.
3. Biology as an independent scientific discipline.
4. Need to study biology.
5. Discuss how biological observations of 18th century that lead to major discoveries.
6. Examples from Brownian motion and the origin of thermodynamics, observation of Robert Brown and Julius Mayor.

INTRODUCTION OF SCIENCE

The word science implies the knowledge, understanding and implementation of phenomenon occurring in the universe relevant to human beings. It is learned through experiments and observation in a particular area or branch of scientific study such as biology, physics, chemistry or mathematics or any other branch of the natural or physical science.

Integration of Branches of Science

Science is broadly studied in four major branches, i.e. **Biology, Physics, Chemistry** and **Mathematics**. These branches are further divided into various subjects of study. Although no perfect definition of these branches can be given but to understand, we can say that biology is the science of living organism, chemistry is the study of matter, physics is the study of force and energy and mathematics is a study of derivations and calculations.

All these branches of science are not a separate entity in itself; rather they are integrated through various functions and phenomenon. For example, in biology the basic unit of life is cell and cell itself contains many types of chemical and enzymes to produce energy and other functions and the various functions like growth, movement involve mathematical calculations. Now, we understand that there is interlining of various branches of science.

To draw out comparison between biology and engineering we will discuss the following examples.

Eye and Camera

In Fig. 1.1 and Tables 1.1 and 1.2 structure of camera and human eye along with the similarities and difference is explained.

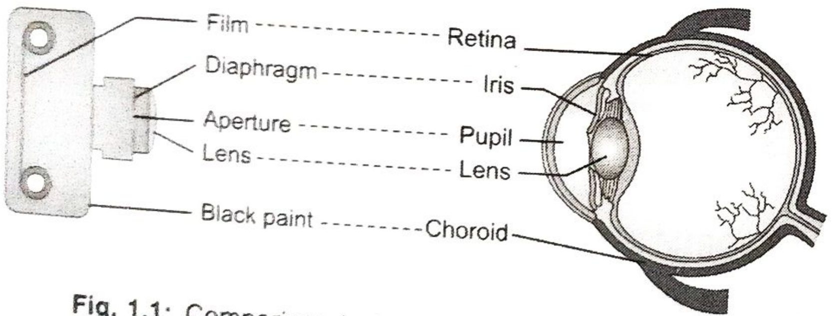

Fig. 1.1: Comparison between camera and human eye

Bird and Aircraft

Both birds and planes are capable of flying and the science has shown that a principle behind this ability of flying in both cases is same but the mechanism is different.

The basic principle of flying is based on Bernoulli's principle

The particles in air are always moving. Air like a fluid will always move from a high pressure area to a low pressure. He found that fast moving air has lower pressure and slow moving

Table 1.1 Similarities between camera and human eye

Part of the camera	*Corresponding part of an eye*	*Function*
Aperture	Pupil	Light enters the eye through the pupil/aperture
Diaphragm	Iris	The iris/diaphragm regulates the amount of light entering the eye/camera.
Lens	Lens	Focus light and image on the retina in eye and film in camera
Film	Retina	The part on which images are formed
Black paint	Choroid	The dark-colored melanin pigment in the choroid and black paint in camera absorbs light and limits reflections within the eye that could degrade vision

Table 1.2 Differences between camera and human eye

Camera	*Human eye*
Focal length of lens is fixed	Focal length of the lens can be changed
Photographic film retains the image permanently	Retina retains the impression of an image for only 1/16th second
A photograph has to be changed for getting next image	Same retina can be used for viewing unlimited images
Image is formed on photographic film and processing can be done through computer	Image is formed on retina which is further processed in brain

air has higher pressure. It is this Bernoulli's principle that helped us how birds and airplanes can fly.

When air rushes past the wing of a plane, it flows above and below the wing. The top part of the wing is rounded and the bottom is fairly straight. Therefore, air rushing over the top of the wing has to travel a greater distance to the back of the wing compared to the bottom (Fig. 1.2).

As a result, the air on the top of the wing has to travel faster to keep up with the air underneath. This creates a low pressure area on the top of the wing and high pressure area on the bottom. The difference of pressures on the surfaces of the wing creates **lift** (the upward force that keeps planes and birds aloft.)

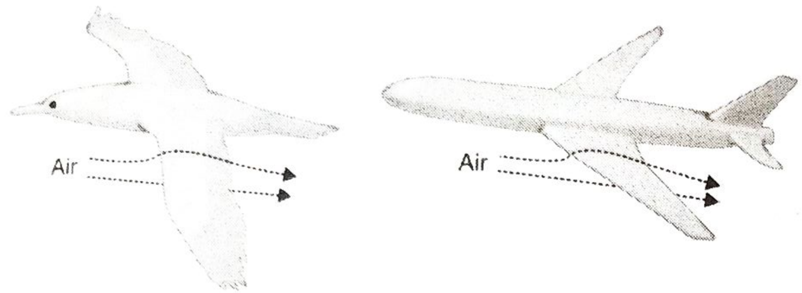

Fig. 1.2: Forces that act on birds during flight

1. **Lift:** The force that pushes upward, created by the movement of air over and under the wings.
2. **Drag:** The force of the air pressing against the bird and slowing them down.
3. **Thrust:** The force that moves the bird forward, caused when a bird flaps its wings.
4. **Propulsion:** It means to push forward or drive an object forward. A propulsion system is a machine that produces thrust.

   Newton's Third Law: For every action there is an equal and opposite reaction. Thrust often comes from muscles or engines.

Characteristics of Birds

Important things that birds have that help them keep their weight low are:

1. **Feathers**—are light, flexible, used for protection and also to keep the bird warm.
2. **Hollow bones**—are very light
3. Strong muscles.

A comparison between flying of aeroplane and flying of birds is shown in Table 1.3.

Table 1.3 Comparison between flying of aeroplanes and birds

Function	*Part of the aeroplane*	*Part of the bird*
Lift	Propellers/airfoil	Muscles
Drag	Streamlined shape	Light weight skeleton and streamlined shape
Thrust	Movement of aeroplanes and wings by engine	Flapping of wings
Control	Wings	Tail and wings
Propulsion	Engine	Muscles

Biology as an independent scientific discipline

Biology is one of the interesting subjects of science as it is directly related to our day-to-day life. The main difference between biology and other subjects of science that biology is not limited to laboratory only. It goes beyond labs into forest, oceans, hills, etc., i.e. it brings us closer to the nature. Following are the few examples of interesting facts which helps us developing interest in biology as subject:

1. Did you ever wonder why the colour of our blood is red? The answer is the iron present in our blood forms a ring of atoms called porphyrin, the shape of this structure produces the red colour.
2. Human bone is an excellent example of a perfect architecture. The femur that supports the weight of our body during walking is more powerful when compared to a solid concrete of the same weight.
3. What's the largest organ of the human body? Quite surprising, but the answer is your skin.
4. The relation between your thumb and your nose is—the length of your thumb is equal to the length of your nose.
5. Every nucleus in the human body has DNA of 6 feet long.
6. Magnetoreception is a type of magnetic compass present in some migratory birds that help them navigate using the Earth's magnetic field.

7. Curious to know how **dolphins** sleep? Then, here you go, dolphins sleep half awake. They keep one eye open while they consciously breathe and float on the water surface.
8. The **ostrich egg** is the biggest in the world. It equals to the volume of as much as 30 chicken eggs.
9. The life of an eyelash is no more than 5 months.
10. What is the largest flower in the world? **Rafflesia Arnoldii.** It can grow as big as an umbrella.
11. Now, that you know about the world's largest flower, you must also know about the world's smallest flowering plant, **Wolffia**. One full bouquet of its flowers fits on the head of a push pin.
12. Armadillos spend about 80% of their life asleep! Did you know?
13. How do ants eat? Want to know? Ants cannot chew their food, they move their jaws sideways like scissors to extract the juices from the food.
14. In seahorses, the male gives birth to a young one.
15. Do you know human's nose and ears? They do not stop growing

Need to Study Biology

Biology is an interesting subject that has been intriguing scientific minds for several centuries. Biology has an endless array of species (at least as of now because there are an estimated 8.7 million species on earth out of which only 1.9 million species have been discovered, so there is a long way to go). Every creation which is a part of nature is so adorable and unique in its own way.

Biology exists every second—when we inhale and exhale each time, respiration is taking place within our bodies, each cell receives oxygenated blood and releases carbon dioxide and other excretory wastes.

Let aside other species, we haven't yet understood our own bodies completely. How is it that our hearts work so tirelessly throughout our life span, how is it that we are able to interpret even minute emotions and gestures without even understanding the mechanism behind it? How is it that each one

of us is able to perceive things differently? What exactly is consciousness? The list of questions seeking their answers is endless!

Ecology, for example, studies the relationship between animals, plants, and the environment, helping us understand how the things humans and other animals do can hurt or help Nature.

Immunology studies our immune system and how it reacts to all sorts of different threats.

Pathology diagnoses diseases and what causes them, as well as what they do to the body. Virology does the same for the many different viruses that may cause harm to us.

The study of biology has helped humans to understand the similarities between all forms of life. For example, the genetic code that helps to construct all living organisms is very similar in all life forms. The genetic material is stored in the form of DNA for all plants, animals, bacteria and fungi. By studying the DNA of all these different life forms, biologists have determined that all living creatures are related to each other.

Biology has also helped doctors learn how to keep people healthy and fight off disease. Biologists have learned that things called pathogens, which are themselves other living entities, cause diseases. By understanding how these dangerous organisms work, scientists can fight them off. Because of biology, many people have lived long lives as they have been able to avoid diseases.

Biology also studies the origin of diseases and plagues, such as infections, pathologies of animals and damage to plants and trees. Biology encompasses the study of the functions of living beings, enhancement of useful species, factors that cause illnesses, discovery and production of medicines and sustainable use of natural resources. Through biotechnology, biologists find efficient ways to produce food and other supplies for people. They investigate the processes involved in producing various nutritional substances.

Observations of 18th Century

Aristotle was one of these first biologists and pursued finding the core of human intelligence, which he concluded to be the heart. Aristotle was a Greek philosopher who studied hum[an] anatomy and marine science.

1. The work of many naturalist explorers like Humbold[t] (1769–1859), Bonpland (1773–1858) greatly increased European appreciation of the enormous extent of the diversity and geographical variation of plants, animals, and fungi. During the eighteenth century great labors were dedicated to the collection, preservation, and cataloging of flora and fauna.
2. The need to organize the resultant wealth of information motivated the work of Carl Linnaeus (1707–1778), who laid the foundations for the modern system of binomial nomenclature.
3. The chemical discoveries of Lavoisier (1743–1794) were instrumental in the development of physiology and biophysics in the following century.
4. Edward Jenner (1749 –1823) was an English physician and scientist who was the pioneer of smallpox vaccine, the world's first vaccine. The terms "vaccine" and "vaccination" are derived from Variolae vaccinae (smallpox of the cow), the term devised by Jenner to denote cowpox Jenner is often called "the father of immunology", and his work is said to have "saved more lives than the work of any other human".
5. Hanaoka Seishû (1760–1835) was a Japanese surgeon. Hanaoka is said to have been the first to perform surgery using general anesthesia.

Brownian motion and the origin of thermodynamics

During microscopic research performed in 1827, Brown made his biggest discovery. While observing the sexual organs of plants under the microscope, the scientist found that pollen grains seemed to be darting around in a random manner. Curious, Brown studied other substances under the microscope in search of the same movement. He discovered that if particles were of a certain size (or smaller), that the movement continued to occur. Brown observed the same movement in glass and rock particles, and theorized that the movement was not limited to living matter. The botanist concluded that the movement was

caused by some phenomenon of physics and named the phenomenon "Brownian motion." In 1905, Albert Einstein suggested that Brownian motion was the result of the particles colliding with molecules. Nobel Prize winner, Jean Perrin, proved that Einstein's thesis of Brownian motion was correct. Brown's discovery provided the first evidence that proved the existence of atoms. The phenomenon of Brownian motion also led scientists to quantify Avagadro's number—a physical constant for describing random motion.

Brownian motion is the continuous random **movement** of small particles suspended in a fluid, which arise from collisions with the fluid molecules. **Examples of Brownian motion are:**

1. The motion of pollen grains on still water
2. Movement of dust motes in a room (although largely affected by air currents)
3. Diffusion of pollutants in air
4. Diffusion of calcium through bones
5. Movement of "holes" of electrical charge in semiconductors

Importance of Brownian Motion

The initial importance of defining and describing Brownian motion was that it supported the modern atomic theory. Today, the mathematical models that describe Brownian motion are used in mathematics, economics, engineering, physics, biology, chemistry, and a host of other disciplines.

Overview: Robert Mayer

In thermodynamics, **Julius Robert Mayer** (1814–1878) was a German physician and physicist notable for making one of the first statements of the conservation of energy and the mechanical equivalent of heat, namely that "motion is converted into heat" (1841), in contrast to the caloric theory, and for making a crude calculation of the latter.

Observation of Robert Mayer that led to the Concept of Thermodynamics

In 1840, Mayer was travelling in a ship destined for a roundtrip to Java. On this voyage two curiosities came to interest him.

First, he was told by the navigator that during a storm the ocean water becomes warmer. This meant, to Mayer, that the agitation, motion, or mechanical action of the waves had been converted into heat. A second note, observed by Mayer, was that during his blood letting procedures he noticed that the venous blood, which is normally a blue colored type of blood being carried in vessels from the capillaries towards the heart, was redder in color than expected.

Laws of Thermodynamics

1. The first law of thermodynamics is an extension of the law of conservation of energy
2. The second law can also be stated that heat flows spontaneously from a hot object to a cold object (spontaneously means without the assistance of external work)

Automobile engines, refrigerators, and air conditioners all work on the principles laid out by the second law of Thermodynamics. Ever wonder why you can't cool your kitchen in the hot summer by leaving the refrigerator door open? Feel the air coming off the back—you heat the air outside to cool the air inside.

The Zeroth Law states that if A is in thermal equilibrium with B, and B is in equilibrium with object C, then C is also in thermal equilibrium with A.

Examples of the First and Second Law of Thermodynamics

Melting Ice Cube

Every day, ice needs to be maintained at a temperature below the freezing point of water to remain solid. On hot summer days, however, people often take out a tray of ice to cool beverages. In the process, they witness the first and second laws of thermodynamics. For example, someone might put an ice cube into a glass of warm lemonade and then forget to drink the beverage. An hour or two later, they will notice that the ice has melted but the temperature of the lemonade has cooled. This is because the total amount of heat in the system has remained the same, but has just gravitated towards equilibrium, where

both the former ice cube (now water) and the lemonade are the same temperature. This is, of course, not a completely closed system. The lemonade will eventually become warm again, as heat from the environment is transferred to the glass and its contents.

Sweating in a Crowded Room

The human body obeys the laws of thermodynamics. Consider the experience of being in a small crowded room with lots of other people. In all likelihood, you'll start to feel very warm and will start sweating. This is the process your body uses to cool itself off. Heat from your body is transferred to the sweat. As the sweat absorbs more and more heat, it evaporates from your body, becoming more disordered and transferring heat to the air, which heats up the air temperature of the room. Many sweating people in a crowded room, "closed system," will quickly heat things up. This is both the first and second laws of thermodynamics in action: No heat is lost; it is merely transferred.

Flipping a Light Switch

We rely on electricity to turn on our lights. Electricity is a form of energy; it is, however, a secondary source. A primary source of energy must be converted into electricity before we can flip on the lights. For example, water energy can be harnessed by building a dam to hold back the water of a large lake. If we slowly release water through a small opening in the dam, we can use the driving pressure of the water to turn a turbine. The work of the turbine can be used to generate electricity with the help of a generator. The electricity is sent to our homes via power lines. The electricity was not created out of nothing; it is the result of transforming water energy from the lake into another energy form.

KEY POINTS

- Science is broadly studied in four major branches, i.e. **Biology, Physics, Chemistry** and **Mathematics**.

- Both birds and planes are capable of flying and the science has shown that a principle behind this ability of flying in both cases is same but the mechanism is different.
- The basic principle of flying is based on Bernoulli's principle.
- Newton's Third Law: For every action there is an equal and opposite reaction.
- Biology exists every second: When we inhale and exhale each time, respiration is taking place within our bodies, each cell receives oxygenated blood and releases carbon dioxide and other excretory wastes.
- Immunology studies our immune system and how it reacts to all sorts of different threats.
- Pathology diagnoses diseases and what causes them, as well as what they do to the body.
- The genetic material is stored in the form of DNA for all plants, animals, bacteria and fungi.
- Aristotle was a Greek philosopher who studied human anatomy and marine science.
- **Brownian motion** is the continuous random **movement** of small particles suspended in a fluid, which arise from collisions with the fluid molecules.
- **Laws of thermodynamics:**
  1. The first law of thermodynamics is an extension of the law of conservation of energy.
  2. The second law can also be stated that heat flows spontaneously from a hot object to a cold object (spontaneously means without the assistance of external work).

PRACTICE QUESTIONS

Very Short Answer Type Questions

1. Give one example of Brownian motion.
2. What is biology?
3. What is Brownian motion?

4. Give example of first law of thermodynamics.
5. What basic principle of flying is used by birds?

Long Answer Type Questions

1. What is the need to study for biology?
2. Give example of Brownian motion.
3. Give differences between (a) flying bird and aeroplane (b) camera and eye.
4. Which features help a bird to fly?