CHAPTER

2

Solving A Biological Problem

Animation 2.1: Solving A Biological Problem
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Science is the systemized knowledge derived from observations and experiments. These experiments are carried out to determine the principles about how nature operates. Scientists like chemists, biologists and physicists use the same scientific method to make and test new theories.

In this chapter, we will study the steps of biological method. We will study malaria as an example to understand the steps in detail.

2.1 Biological Method

Questions about living things have provided problems that man has investigated to aid his own survival and to satisfy his desire to know. The scientific method in which biological problems are solved, is termed as biological method. It comprises the steps a biologist adopts in order to solve a biological problem.

Biological method has played an important part in scientific research for almost 500 years. From Galileo's experiment (in the 1590s) to current research, the biological method has contributed to the advancements in medicine, ecology, technology etc. Biological method also ensures the quality of data for public use

Man has always been a biologist. He had to be a biologist in order to live. Early in history, he was a hunter of animals and a gatherer of fruits, seeds, roots etc. The more he knew about animals and their habitat, the more successful hunter he was. The more he knew about plants, the better he distinguished between edible and non-edible plants.

2.1.1 Biological problem, hypothesis, deductions and experiments

In biology (like other sciences), new things are being discovered and long-held theories are being modified or replaced with better ones as more data/knowledge is accumulated. This happens when biologists recognize some biological problem and go for its solution. In solving a biological problem, biologist takes following steps;

- Recognition of biological problem
- Observations
- Hypothesis formulation
- Deductions

- Experimentation
- Summarization of results (create tables, graphics etc)
- Reporting the results

The details of these steps are as under:

1. Recognition of the Biological Problem

Biologists go for adopting biological method when they encounter some biological problem. A biological problem is a question related to living organisms that is either asked by some one or comes in biologist's mind by himself.

2. Observations

As the first step in solving a biological problem, biologist recalls his/her previous observations or makes new ones. Observations are made with five senses of vision, hearing, smell, taste and touch. Observations may be both qualitative and quantitative. Quantitative observations are considered more accurate than qualitative ones because the former are invariable and measurable and can be recorded in terms of numbers. Examples of qualitative and quantitative observations are given below.

Qualitative observations	Quantitative observations
• The freezing point of water is colder than the boiling point.	• The freezing point of water 0 °C and the boiling point is 100 °C.
• A liter of water is heavier than a liter of ethanol.	• A liter of water weighs 1000 grams and a liter of ethanol weighs 789 grams.

Observations also include reading and studying what others have done in the past because scientific knowledge is ever-growing.

Biologists can't usually check every situation where a hypothesis might apply. Let's consider a hypothesis:
"All plant cells have a nucleus". Biologist cannot examine every living plant and every plant that has ever lived to see if this hypothesis is false. Instead, biologists generate deduction using reasoning. From the above hypothesis, a biologist can make the following deduction: "If examine cells from a blade of grass, then each one will have a nucleus".

3. Formulation of Hypotheses

Observations do not become scientific observations until they are organized and related to a question.Biologist organizes his/her and others' observations into data form and constructs a statement that may prove to be the answer of the biological problem under study. This tentative explanation of observations is called a hypothesis. It may be defined as a proposition that might be true. A hypothesis should have the following characteristics:

- It should be a general statement.
- It should be a tentative idea.
- It should agree with available observations.
- It should be kept as simple as possible.
- It should be testable and potentially falsifiable. In other words, there should be a way to show the hypothesis is false; a way to disprove the hypothesis.

A great deal of careful and creative thinking is necessary for the formulation of a hypothesis. Biologists use reasoning to formulate a hypothesis.

4. Deductions

In the next step, biologist draws deductions from hypotheses. Deductions are the logical consequences of hypotheses. For this purpose, a hypothesis is taken as true and expected results (deductions) are drawn from it.

Generally in biological method, if a particular hypothesis is true then one should expect (deduction) a certain result. This involves the use of “if-then” logic.

5. Experimentation

The most basic step of biological method is experimentation. Biologist performs experiments to see if hypotheses are true or not. The deductions, which are drawn from hypotheses, are subjected to rigorous testing. Through experimentations, biologist learns which hypothesis is correct.

The incorrect hypotheses are rejected and the one which proves correct is accepted. An accepted hypothesis makes further predictions that provide an important way to further test its validity.

6. Summarization of results

Biologist gathers actual, quantitative data from experiments. Data for each of the groups are then averaged and compared statistically. To draw conclusions, biologist also uses statistical analysis.

What is "Control" in experiments?

In science when doing the experiment, it must be a controlled experiment. The scientist must contrast an "experimental group" with a "control group". The two groups are treated exactly alike except for the one variable being tested. For example, in an experiment to test the necessity of carbon dioxide for photosynthesis, one can contrast the control group (a plant with freely available carbon dioxide) with an experimental group (a plant with no carbon dioxide available). The necessity of carbon dioxide will be proved when photosynthesis occurs in the control group and does not occur in the experimental group.

7. Reporting the results

Biologists publish their findings in scientific journals and books, in talks at national and international meetings and in seminars at colleges and universities. Publishing of results is an essential part of scientific method. It allows other people to verify the results or apply the knowledge to solve other problems.

Study Of Malaria - An Example Of Biological Method

We know malaria is a common disease in many countries including Pakistan. We will go through the history of this disease to know how biology solved the biological problem concerning the cause and transmission of malaria. In ancient times (more than 2000 years ago), physicians were familiar with malaria. They described it as a disease of chills and fevers with recurring attacks. They also observed that the disease was more common among people living in low, marshy areas. It was thought that the stagnant water of marshes poisoned the air and as a result of breathing in this "bad air", people got malaria. This belief led to the name of this disease. The Italian words **"mala"** means bad and **"aria"** means air. For further clarification of the observation, some volunteers drank stagnant water from the marshes. They did not develop malaria.

In the 17th century when the New World (America) was discovered, many plants from America were sent back to Europe to be used as medicines. The bark of a tree known as **quina-quina** was very suitable for curing fevers. It was so beneficial that soon it was impossible to carry enough bark to Europe. Some dishonest merchants began to substitute the bark of another tree, **cinchona** which closely resembled quina-quina. This dishonesty proved much valuable for mankind. Cinchona bark was found to be excellent for treating malaria. We now know the reason: cinchona bark contains **quinine** that is effective in treating the disease

At that time, physicians treated malaria with cinchona without understanding the cause of malaria. Two hundred years later, it was found that some diseases are caused by tiny living organisms. After this discovery, it also became a belief that malaria, too, might be caused by some microorganism. In 1878, a French army physician **Laveran** began to search for the "cause" of malaria. He took a small amount of blood from a malarial patient and examined it under microscope. He noticed some tiny living creatures. His discovery was not believed by other scientists. Two years later, another physician saw the same creatures in the blood of another malarial patient. Three years after the second discovery, the same creatures were observed for third time. The organism was given a name ***Plasmodium***.

In the last part of nineteenth century, many different causes of malaria were being suggested. By that time, there were four major **observations** about malaria.

- Malaria and marshy areas have some relation.
- Quinine is an effective drug for treating malaria.
- Drinking the water of marshes does not cause malaria.
- Plasmodium is seen in the blood of malarial patients.

We know that a scientist uses whatever information and observation he has and makes one or more hypotheses. The **hypothesis** made in this case was;

"Plasmodium is the cause of malaria."

Scientist does not know whether his hypothesis is true or not, but he accepts it may be true and makes **deductions**. One of the deductions from the above hypothesis was;

"If Plasmodium is the cause of malaria, then all person ill with malaria should have Plasmodium in their blood."

The next step was to test the deduction through **experiments** which were designed as;

"Blood of 100 malarial patients was examined under microscope. For the purpose of having a control group, the blood of 100 healthy persons was also examined under microscope."

The results of experiments showed that almost all malarial patients had Plasmodium in their blood while 07 out of 100 healthy persons also had Plasmodium in their blood (now we know that Plasmodium in the blood of healthy people was in incubation period i.e. the period between the entry of parasite in host and the appearance of symptoms). The results were quite convincing and proved that the hypothesis "Plasmodium is the cause of malaria" was true.

Malaria has killed more people than any other disease. The account of malaria is an example of a biological problem and of how such problems are solved.

Next biological problem was to learn about "How *Plasmodium* gets into the blood of man". Biologists were having following observations;

- Malaria is associated with marshes.
- Drinking water of marshes does not cause malaria.
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From these observations, it can be concluded that Plasmodium was not in the marsh water. But it must be carried by something that comes to marsh water. In 1883, a physician **A. F. A**. King, listed 20 observations. Some important observations of King were:

- People who slept outdoors were more likely to get malaria than those who slept indoors;
- People who slept under fine nets were less likely to get malaria than those who did not use such nets; and
- Individuals who slept near a smoky fire usually did not get malaria.
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On the basis of these observations King suggested a hypothesis:

"Mosquitoes transmit Plasmodium and so are involved in the spread of malaria."

Following deductions were made considering the hypothesis as true i.e. If mosquitoes are involved in the spread of malaria then;

"Plasmodium should be present in mosquitoes."

"A mosquito can get Plasmodium by biting a malarial patient."

In order to test the above deductions, **Ronald Ross:** a British army physician working in India in 1880's; performed important experiments. He allowed a female **Anopheles** mosquito to bite a malarial patient. He killed the mosquito some days later and found Plasmodium multiplying in mosquito's stomach.

In fact quinine was the only effective remedy for malaria from the 17th to the 20th century.

The next logical experiment was to allow an infected mosquito (having Plasmodium) to bite a healthy person. If hypothesis was true, the healthy person would have got malaria. But scientists avoid using human beings for experiments when results can be so serious. Ross used sparrows and redesigned his experiments. He allowed a female **Culex** mosquito to bite on the sparrows suffering from malaria. Some of the mosquitoes were killed and studied at various times. Ross found that Plasmodium multiplied in the wall of mosquito's stomach and then moved into mosquito's salivary glands. He kept some mosquitoes alive and allowed them to bite healthy sparrows. Ross found that the saliva of the infected mosquito contained Plasmodia (plural of Plasmodium) and these entered the sparrow's blood. When he examined the blood of these previously healthy sparrows, he found many *Plasmodia* in it.

In the end, the hypothesis was tested by direct experimentation on human beings. In 1898, Italian biologists allowed an *Anopheles* mosquito to bite a malarial patient. The mosquito was kept for a few days and then it was allowed to bite a healthy man. This person later became ill with malaria. In this way, it was confirmed that mosquitoes transmit Plasmodium and spread malaria. (Figure 2.1)

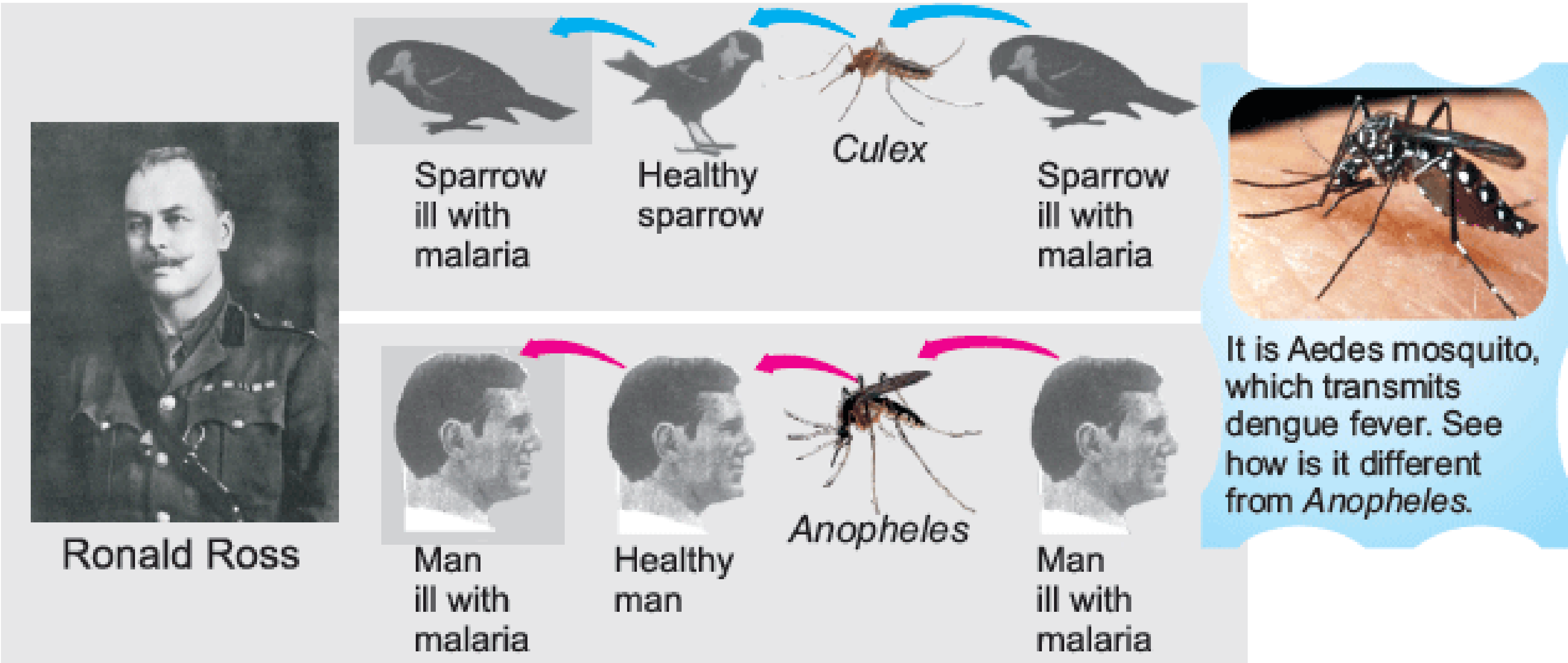

Figure 2.1 : Malaria in sparrow and man is transmitted by *Culex* and *Anopheles* mosquitoes respectively

? While testing the hypothesis that plasmodium is the cause of malaria, what would be the control group of the experiment? Blood of malarial patients or blood of healthy persons?

Blood of healthy persons

2.1.2 Theory, law and principle

When a hypothesis is given a repeated exposure to experimentation and is not falsified, it increases biologists' confidence in hypothesis. Such well-supported hypothesis may be used as the basis for formulating further hypotheses which are again proved by experimental results. The hypotheses that stand the test of time (often tested and never rejected), are called **theories**. A theory is supported by a great deal of evidence.

Productive theory keeps on suggesting new hypotheses and so testing goes on. Many biologists take it as a challenge and exert greater efforts to disprove the theory. If a theory survives such doubtful approach and continues to be supported by experimental evidence, it becomes a **law or**

principle. A scientific law is a uniform or constant fact of nature. It is an irrefutable theory. Examples of biological laws are Hardy-Weinberg law and Mendel's laws of inheritance.

When a female mosquito pierces the skin with her mouthparts, she injects a small amount of saliva into the wound before drawing blood. The saliva prevents the blood from clotting in her food canal.

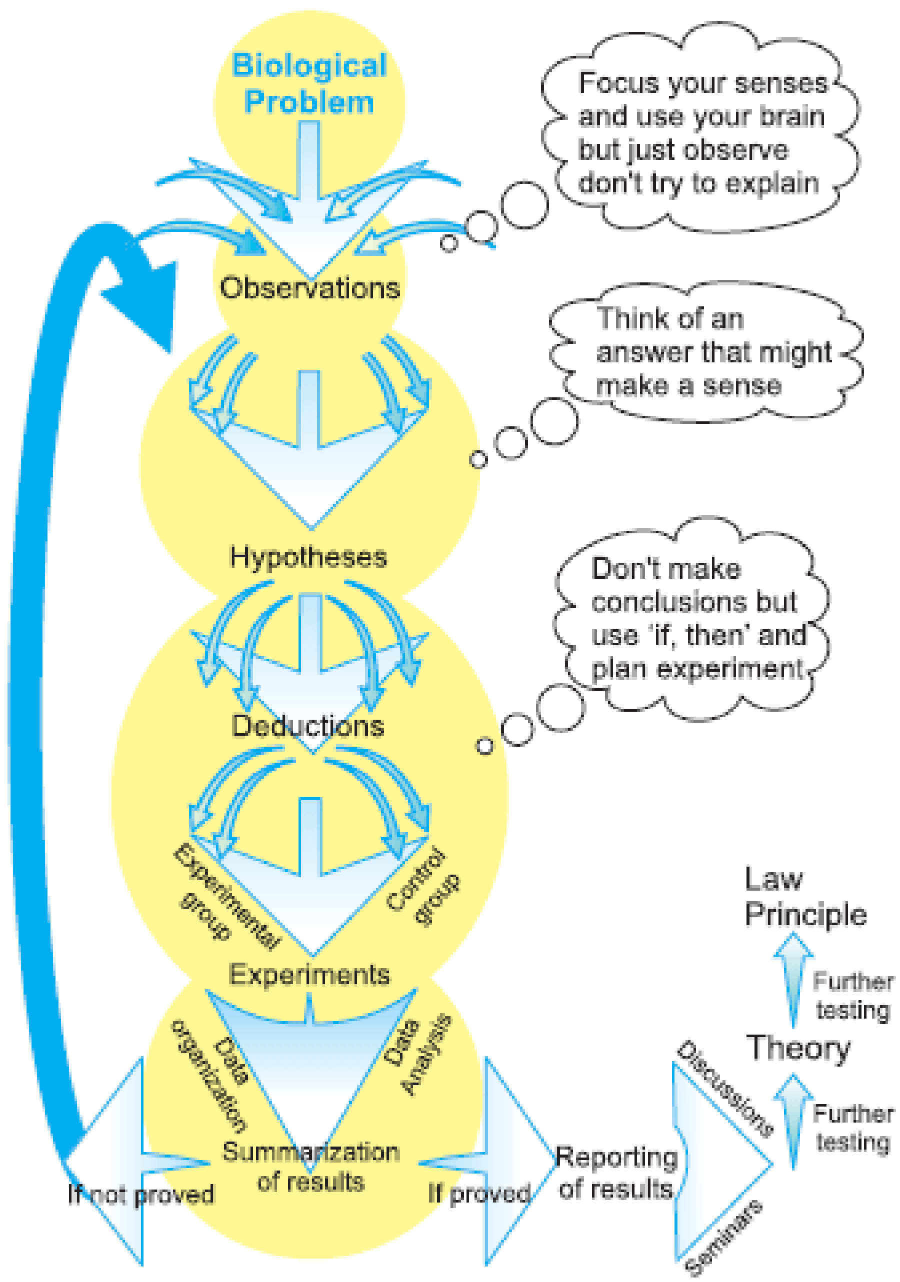

Figure 2.2: Biological method

Female mosquitoes need the blood of mammals or birds for the maturation of their eggs.

The welts that appear after the mosquito leaves is not a reaction to the wound but an allergic reaction to the saliva. In most cases, the itching sensation and swellings subside within several hours.

2.2 Data Organization And Data Analysis

Data organization and data analysis are important steps in biological method. Data can be defined as the information such as names, dates or values made from observations and experimentation.

Data organization

In order to formulate and then to test hypotheses, scientists collect and organize data. Prior to conducting an experiment, it is very important for a scientist to describe data collection methods. It ensures the quality of experiment. Data is organized in different formats like graphics, tables, flow charts, maps and diagrams.

Data analysis

Data analysis is necessary to prove or disprove a hypothesis by experimentation. It is done through the application of statistical methods i.e. ratio and proportion. When a relation between two numbers e.g. 'a' and 'b' is expressed in terms of quotient (a/b), it is called the ratio of one number to the other. Ratio may be expressed by putting a division (÷) or colon (:) mark between the two numbers. For example the ratio between 50 malarial patients and 150 normal persons is 1:3.

Proportion means to join two equal ratios by the sign of equality (=). For example; a:b = c:d is a proportion between the two ratios. This proportion may also be expressed as a:b::c:d. When three values in a proportion are known, the fourth one (X) can be calculated.

For example, a biologist can calculate how many birds will get malaria when he allows infected mosquitoes to bite 100 healthy sparrows. In the previous experiment he noted that when he allowed mosquitoes to bite 20 sparrows, 14 out of them got malaria. Now he uses the proportion rule.

1st Ratio 14:20 (14 out of 20) 2nd Ratio X:100 (How many out of 100)	Proportion 14:20 :: X:100

$$\frac{X}{100} = \frac{14}{20} \longrightarrow X \times 20 = 100 \times 14 \longrightarrow X = \frac{100}{20} \times 14 \longrightarrow X = 70$$

It means 70 out of 100 sparrows get malaria

Statistics are thus a means of summarizing data through the calculation of mean value. This step is very important as it transforms raw data into information, which can be used to summarize and report results

2.3 Mathematics: As An Integral Part Of Scientific Process

Biological method also involves the use of applied mathematics to solve biological problems. Major biological problems in which knowledge of mathematics is used include gene finding, protein structure, and protein-protein interactions etc. Bioinformatics refers to the computational and statistical techniques for the analysis of biological data.

UNDERSTANDING THE CONCEPTS

1. Describe the steps involved in biological method taking malaria as an example.
2. If a test shows that some people have Plasmodium in their blood but they do not show any symptoms of malaria, what hypothesis would you formulate to answer this problem?
3. How the principles of ratio and proportion are used in biological method.
4. Justify mathematics as an integral part of the scientific process.

SHORT QUESTIONS

1. Differentiate between theory and law.
2. Quantitative observations are better in biological method. How?

THE TERMS TO KNOW		
Bioinformatics	Deduction	Law
Biological Method	Experiment	Observation
Biological Problem	Experimental Group	Theory
Control Group	Hypothesis	

INITIATING AND PLANNING

1. Identify and pose meaningful, answerable scientific questions.
2. For a given biological problem;
3. Formulate and test a working hypothesis.
4. Write instructions for conducting investigations.
5. Organize data appropriately using techniques such as tables and graphs.
6. Analyze data to make predictions, decisions, or draw conclusions.
7. Confirm, modify, or reject a hypothesis using data analysis.
8. Use ratio and proportion in appropriate situations to solve problems.

ON-LINE LEARNING

1. en.wikipedia.org/wiki/Scientific_method
2. www.sciencebuddies.org/science-fair
3. www.visionlearning.com/library
4. www.scientificmethod.com/www.scientificmethod.com