SOLVING A BIOLOGICAL PROBLEM

Chapter 2

Major Concept

In this Unit you will learn:

- Biological Method
  - Scientific problem, Hypotheses, Deductions and Experiments
  - Theory, Law and Principle
  - Data organization and Data analysis
  - Mathematics as an integral part of the Scientific Process

Science is the systematic study of nature and how it affects us and the environment. It is a body of knowledge that is constantly changing through the use of better and more accurate tools for investigation. At the core of biology and other sciences lies a problem-solving approach called the scientific method.

The scientific method is a series of steps followed by scientific investigators to answer specific questions about the natural world.

2.1 BIOLOGICAL METHOD

As you know that biology is the branch of science concerned with the study of living things, or organisms. The system of advancing knowledge by formulating a question, collecting data about it through observation and experiment, and testing a hypothetical answer about living things is called biological method.

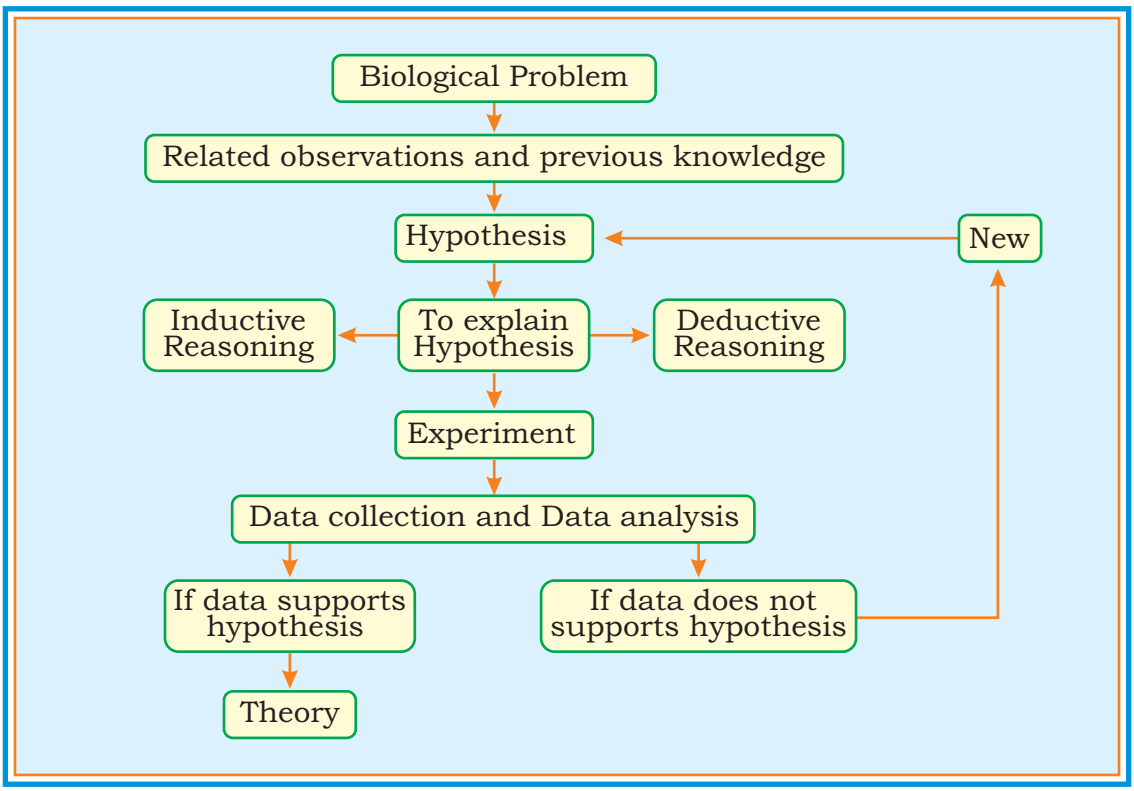


Figure 2.1 The steps involved in a biological method

2.1.1 Biological problem, Hypothesis, Deduction and Experiments:

Biological problem is a set of questions to be solved, about the natural world. These problems can be environmental, ecological, health related, etc. No matter what types of problems are being studied, scientists use the same problem-solving method to find answers that are logical and supported by evidence. Here we take an example of malaria (the greatest killer disease of man for centuries). You are familiar with the disease of malaria which spread through a female Anopheles mosquito. Previously the cause of malaria was unknown. It was thought that the malaria is caused by “bad air” (Latin word: 'mala' means bad, and 'aria' means air). This problem is solved when a Scientist identified the reason of malaria.

Observation:

The first step is to identify the reason of the problem followed by the formulation of a question about what has been observed. The solution of biological problem starts with observation. Your observation can be on anything from plant movement to animal behavior. An observation is a statement of knowledge gained through the senses (qualitative) or through the use of scientific equipment (quantitative).

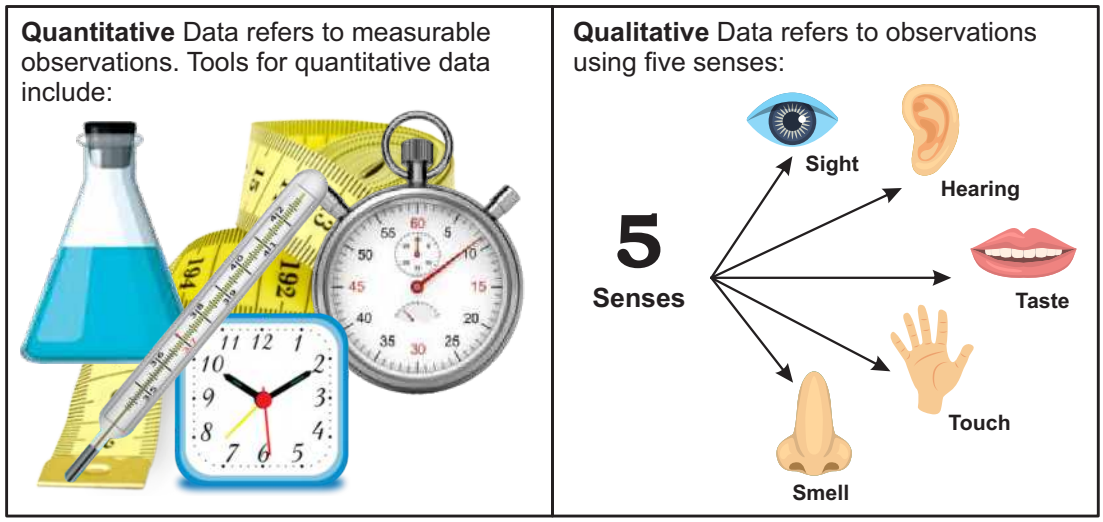


Figure 2.2 The qualitative and quantitative observation

About 280 million people suffer from malaria in over 100 countries, and more than 2 million die every year from the disease.

In 1880, a French physician, ***Laveran***, studied the blood sample of malaria patient under microscope and observed tiny creatures in it and named as ***Plasmodium***. So the observation was made that Plasmodium is present in the blood of malaria patients.

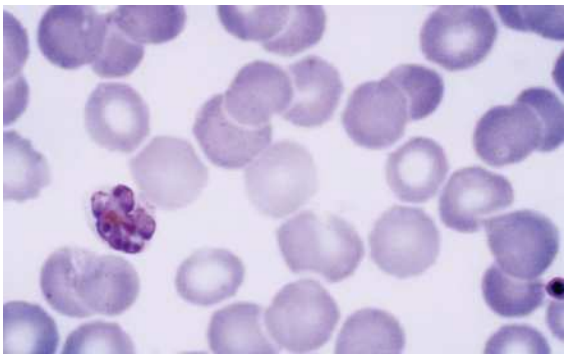


Figure 2.3 Plasmodium in blood sample

Hypothesis:

Hypothesis is a key component of the scientific process. It is defined as "the intelligent guess made by a scientist in the form of statement". It is important to note that a hypothesis must be testable. That means, you should be able to test your hypothesis through experimentation. Your hypothesis must either be supported or falsified by your experiment.

For Example: In malaria case, an intelligent guess is made after observation that **Plasmodium is the cause of malaria**. But it is only a guess which can be presented as a hypothesis.

Reasoning:

Biologists collect information about the problem and formulate the hypothesis by using a reasoning process i.e. 'inductive reasoning and deductive reasoning'.

Figure 2.4 A female Anopheles mosquito

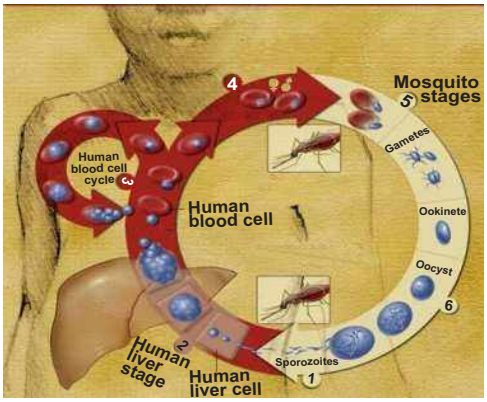


Figure 2.5 The Malarial Parasites (Plasmodium)

- **Inductive reasoning** moves from specific to general e.g. Shark is a fish. All fishes have scales therefore sharks also have scales.
- **Deductive reasoning** moves from general to specific. It is based on "if-then" statement. Deductive reasoning can be tested and verified by experiments. In malaria case, the following deduction is made:

"If *Plasmodium* is the cause of malaria, then all the malaria patient should have Plasmodium in their blood" as shown in figure 2.3.

Experiment:

Once a problem has been observed and a hypothesis is suggested, the next step in the scientific method is to design an experiment based on reasoning.

Experiment is a practical performance of a scientist to identify the real cause of a problem based on inductive and or deductive reasoning. A key assumption is that the experiment will be repeated many times by other scientists.

Scientist performs two types of test i.e. **control group** and **experimental group**. To find out the cause of malaria, blood samples of 100 malaria patients (experimental group) and the blood samples of 100 healthy persons (control group) were examined under microscope.

Figure 2.6 Hypothesis, an intelligent guess which leads the scientist to perform Experiment.

Result

The results are where you report what happened in the experiment. That includes detailing all observations and data made during your experiment. Result verifies the hypothesis. In the case of malaria, it was found that *all the malaria patients (experimental group) had Plasmodium in their blood whereas the blood samples of healthy persons (control group) were free from Plasmodium.*

Conclusion:

The final step of the scientific method is developing conclusion. This is where all the results from the experiment are analyzed and a determination is reached about the hypothesis. If your hypothesis was supported, its great. If not, repeat the experiment or think of other ways to improve your procedure.

Example: Conclusion is made that *"Plasmodium is the cause of malaria".*

2.1.2 Theory, Law and Principle:

Theory:

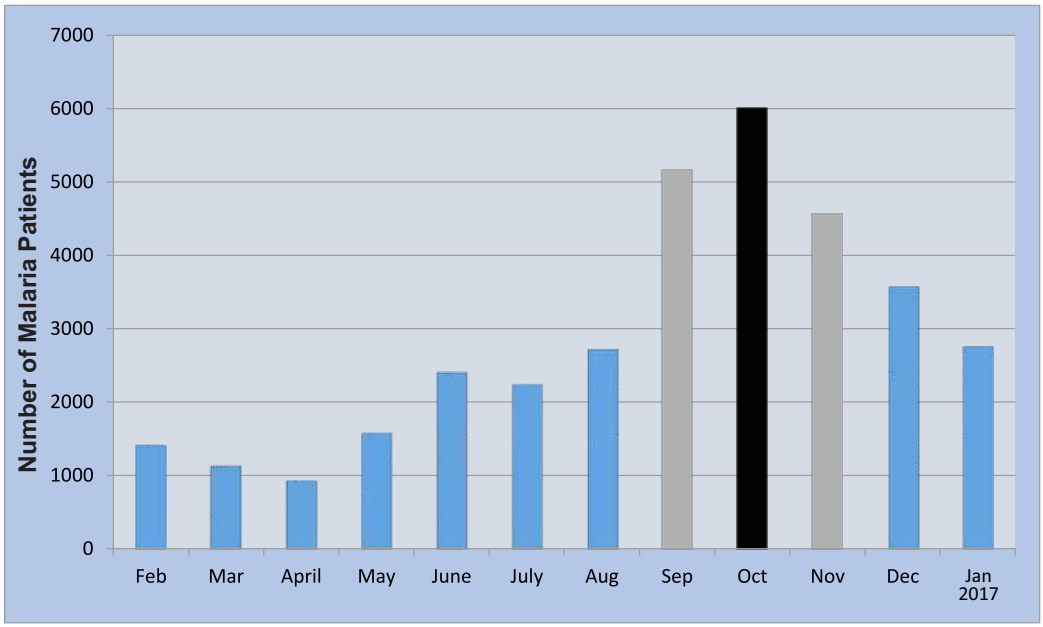
Scientists use the word "theory" in a very different way than non-scientists. When many people say "I have a theory", they really mean "I have a guess". Scientific theories, on the other hand, are well-tested and highly reliable scientific explanations of natural phenomena. They unify many repeated observations and data collected from lots of experiments. For example Theory of Evolution.

Law and principle:

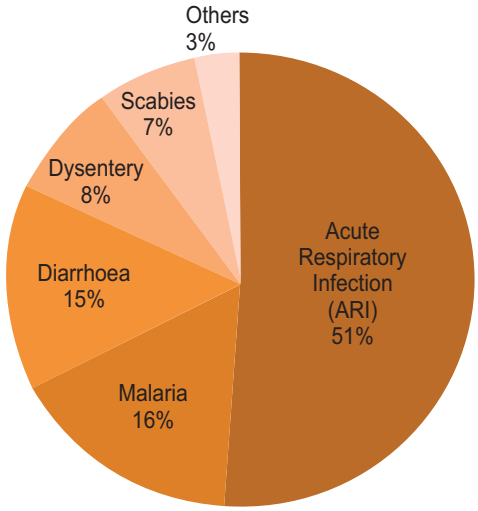
A scientific law is a uniform or constant fact of nature, it is virtually an irrefutable theory. Biology is short in laws due to puzzling nature of life.

2.1.3 Data organization and Data analysis:

For data organization you will prepare a table or graph of the data. Don't throw out data points you think are bad or that don't support your predictions. Some of the most incredible discoveries in science were made because the data looked wrong! Once you have recorded the data, you may need to perform a mathematical analysis to support or refuse your hypothesis.



A bar chart showing the trend of malaria cases reported in Sindh 2016-17



A Pie Chart showing Infectious diseases in Pakistan (2006)

In data analysis, the statistical methods (ratio and proportion) are applied. **Ratio** is a comparison of two values expressed as a quotient (1st/2nd). Example: A flower has 4 sepals and 12 petals. The ratio of sepals to petals is 4:12. This ratio can also be expressed as an equivalent fraction 1:3. A **Proportion** is an equation stating that two ratios are equal. Example: 4:12::1:3.

2.1.4 Mathematics as an integral part of the scientific process:

Imagine that you are a biologist studying the insect population. You go into the field and count the population sample in a specific region, then compare your sample with other regions to get population estimated. At every step of this process, you depend upon mathematics to measure, predict, and understand natural phenomena.

Mathematical biology is a field of research that examines mathematical representations of biological systems. One key role of mathematics in biology is the creation of **mathematical models**. There are equations or formulas that can predict or describe natural occurrences, such as organism behavior patterns, population changes over time, structure of protein, height of living organisms, population of an endangered species, bacterial growth and so on. Finally we can say that mathematics plays a critical role in better understanding the natural world.

Summary

- Science is the systematic study of nature and how it affects us and the environment.
- The biological method is the stepwise process in which a scientist finds out the reason of any biological problem about living things.
- An observation is a statement of knowledge gained through the senses (qualitative) or through the use of scientific equipment (quantitative).
- Your question should tell what it is that you are trying to discover or accomplish in your experiment.
- A hypothesis is an idea that is suggested as an explanation for a natural event, particular experience, or specific condition that can be tested through definable experimentation.
- The deductive reasoning involves the use of “if-then” logic. It moves from general to specific.
- Result includes detailing all observations and data made during your experiment.

- Conclusion is where all the results from the experiment are analyzed and a determination is reached about the hypothesis.
- Theories are the well-tested and highly reliable scientific explanations of natural phenomena.
- A scientific law is a uniform or constant fact of nature.
- Mathematical biology is a field of research that examines mathematical representations of biological systems.

Review Questions

1. Encircle the correct answer:

(i) Select the correct sequence of biological method.

(a) Law → Theory → Reasoning → Hypothesis

(b) Hypothesis → Theory → Law → Reasoning

(c) Hypothesis → Reasoning → Theory → Law

(d) Law → Hypothesis → Reasoning → Theory

(ii) Select the odd one

(a) Theory (b) Law

(c) Hypothesis (d) Ratio

(iii) Field of research that examines mathematical representations of biological system called.

(a) Ratio (b) Mathematical biology

(c) Proportion (d) Law

(iv) Biological method involves all of the following except.

(a) Data collection (b) Observation

(c) Experiment (d) Proportion

(v) Scientific reasoning moves from specific to general.

(a) Inductive (b) Deductive

(c) Observation (d) Both a and b

(vi) Quantitative observation is the use of

(a) Senses (b) Equipment

(c) Guess (d) Ratio

(vii) Equation stating that two ratios are equal

(a) Ratio (b) Proportion

(c) Guess (d) Senses

(viii) The comparison of two values is called

(a) Ratio (b) Proportion

(c) Graph (d) Table

(ix) What is a hypothesis?

(a) The same thing as an unproven theory.

(b) A tentative explanation that can be tested and is falsified.

(c) A verifiable observation.

(d) A fact based on quantitative data that is falsified.

(x) In data organization, which method is mostly useful?

(a) Table (b) Graph

(c) Ratio (d) Both a and b

2. Fill in the blanks:

(i) Problem solving approach of biology and other sciences called_____.

(ii) Solution of biological problem starts with_____.

(iii) The key component of the scientific process is _____.

(iv) Scientific reasoning based on "if-then" statement called _____.

(v) Final step of the scientific method is developing _____.

(vi) The uniform or constant fact of nature, virtually an irrefutable theory is _____.

(vii) Once you have the data, you may need to perform _____ analysis.

(viii) The equation stating that two ratios are equal is called _____.

(ix) Ratio is comparison of _____ values.

(x) The cause of malaria is _____.

3. Define the following terms:

(i) Ratio (ii) Biological method (iii) Graph

(iv) Hypothesis (v) Law (vi) Inductive reasoning

(vii) Conclusion (viii) Proportion (ix) Observation

(x) Mathematical models

4. Distinguish between the following in tabulated form:

(i) Theory and Law

(ii) Inductive reasoning and deductive reasoning

5. Write short answers of following questions:

(i) Theory is highly reliable scientific explanations, why?

(ii) Why biological sciences need mathematical models?

(iii) Draw a chart showing steps involved in biological methods.

(iv) Why table or graph is necessary for data organization?

(v) Why experiment is necessary for theory?