# SLO 2: Solving a Biological Problem

## 2.1 Biological Method

### 2.1.1 Explain Steps Involved In The Biological Method

**Recognition Of A 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 someone or comes in biologist's mind by himself.

**Observation (Qualitative And Quantitative)**

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 0C and the boiling point is 100C. |
| 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.

**Building Up Hypotheses Via Inductive And Deductive Reasoning**

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. A hypothesis should have the following characteristics:

1. It should be a general statement.
2. It should be a tentative idea.
3. It should agree with available observations.
4. It should be kept as simple as possible.
5. It should be testable and potentially falsifiable.

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.

- 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.

**Deducing**

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.

**Devising Experiments**
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.

**Inferring And Reporting 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. Biologists publish their findings in scientific journals and books, in talks at national and international meetings and in seminars at colleges and universities. It allows other people to verify results or apply knowledge to solve other problems.

**Proposing Theory**
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.

**Putting Forward Law/ Principle**
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.

## 2.1.2 Differentiate Between Hypothesis, Theory And Law

**Hypotheses:**
Hypothesis is defined as "the intelligent guess made by a scientist in the form of statement". A hypothesis must be testable through experimentation. Hypothesis must either be supported or falsified by experiment.

**Theory:**
Scientific theories are well-tested and highly reliable scientific explanations of natural phenomena. They unify many repeated observations and data collected from lots of experiments.

**Law:**
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 Design A Solution For A Biological Problem By Following The Scientific Method

1. Formulate a working hypothesis
2. Write instructions for conducting investigations or following a procedure
3. Design an appropriate experiment with a control group
4. Dependent, independent and constant variables
5. Organize data appropriately using techniques such as tables and graphs
6. Plot a bar graph, line graph and pie chart from the given set of biological data
7. Interpret bar graph, line graph, pie chart, scatter plot chart and histogram
8. Analyze data to make predictions, decisions or make conclusions

## 2.1.4 Justify That Science Is A Collaborative Field That Requires Interdisciplinary Researchers Working Together To Share Knowledge And Critique Ideas.

### 1. The Interdisciplinary Nature (Inter-relationship)

Science is no longer "siloed." A single biological discovery often requires the laws of Physics, the formulas of Mathematics, and the reactions of Chemistry. For example, to understand how a human limb moves (Biology), we must apply the principles of levers and pulleys (Physics). Or, to predict the spread of a virus like COVID-19, biologists must work with mathematicians to create data models and graphs. Without these other fields, biology would only be "descriptive" (what happens) rather than "predictive" (how and when it happens).

### 2. Knowledge Sharing (Global Collaboration)

Scientific advancement depends on building upon the work of others. No researcher starts from zero. Researchers publish their findings globally. For instance, a geneticist in Pakistan can use DNA sequences mapped by a scientist in the UK to study local hereditary diseases. For example; The Human Genome Project. This is the ultimate example of collaboration. Thousands of scientists from different countries worked together for 13 years to map human DNA—a task impossible for a single lab.

### 3. Peer Review and Critique (Intellectual Honesty)

Science is self-correcting because it requires researchers to critique each other's ideas. Before a discovery is accepted, other experts in the field must verify the experiments and the data. They look for errors, biases, or "flukes." In science, being "proven wrong" is not a failure; it is progress. When one scientist critiques another's hypothesis, it leads to more rigorous testing and more accurate facts. Critique ensures that only verified, evidence-based information reaches the public, maintaining the integrity of scientific knowledge.