# 7 Hypothesis

## 7.1 Introduction

In scientific method, one of the important step is **formulation of a hypothesis** when scientists are faced with a situation or a problem which they are not able to understand and explain then the scientific inquiry begins.

Scientific investigation may be either in the field of natural sciences like physics, chemistry or social sciences like Sociology, Anthropology etc., when scientist observe nature they come across certain facts, events or situations which they are not able to explain. These are problems faced by scientist. Feeling of a problem is the starting point of scientific investigation. Next important step is to formulate a hypothesis. **Unless a hypothesis is formed scientific investigation cannot proceed further. Thus, hypothesis gives a direction to scientific investigation and is an important step in scientific investigation.**

It is therefore necessary to know what hypothesis is and how it is established in science.

## 7.2 Definition and Nature of hypothesis

Scientist's investigation begins with the formation of hypothesis. The word hypothesis is derived from the Greek word **'hypo'** which means **'under'** and **'thithenai'** means **'to place'**.

**Coffey** defines hypothesis as "An attempt at explanation, a provisional supposition made in order to explain scientifically some facts or phenomenon."

In simple words **hypothesis is defined as a tentative solution given to the problem.**
For e.g - Since childhood, Edward Jenner had heard that in spite of getting cow pox blisters on their hands, milkmaids did not develop small pox. To explain this situation, he formulated a hypothesis that 'the pus in the blisters might have protected the milkmaids from small pox.' This was a provisional supposition. **Thus hypothesis is a guess work as to how facts are connected.**

## 7.3 Characteristics of Hypothesis

### (1) It is an important stage in scientific investigation :

Every scientific investigation starts with the problem for which scientist intends to find solution. He begins by assuming a possible explanation on the basis of which he starts investigation. **Hypothesis is like guiding post** which gives direction to scientific investigation. No scientific investigation is possible without hypothesis. Unless a hypothesis is formed scientists would not know what facts to observe and what experiments to conduct in order to find the solution to the problem.

***For example :*** Discovery of Neptune.

Astronomers had calculated the orbit of planet Uranus, on the basis of the gravitational pull of then known planets. But, in 1820, scientists Bouvard observed that there was a deviation in this calculated orbit. Astronomers **advanced the hypothesis that there is a planet beyond Uranus** which is disturbing the gravitational force of Uranus.

The great Berlin telescope was turned towards that direction and they found the planet. This planet was named Neptune. Hence the hypothesis was verified to be true.

### (2) Attempts at explanation

Hypothesis is an attempt at explaining observed facts which scientist are unable to explain. Hypothesis does not explain the fact unless it is verified to be true. On the basis of this possible explanation the investigator proceeds to collect data through observation and may use the experiment to verify it. Once the hypothesis is verified it becomes the explanation of the problem.

### (3) Provisional :

Every hypothesis is always provisional in character. It is suggested as a likely solution. It

is merely a tentative supposition or suggestion or simply a claim to explain the fact. It may turn out to be a right explanation or may turn out to be a wrong one. There is no finality about the solution provided by it.

**(4) It is an organising principle -**

The aim of science is to understand and explain facts. This is done by introducing order in facts.

In fact there is an order in nature but this order cannot be perceived the way in which one can perceive facts. One has to find out this order. This is what science attempts to do. At initial stage of scientific inquiry one fails to understand the connection between innumerable facts and events in nature. Facts appear to be scattered, isolated and unrelated to each other. But once the hypothesis is verified to be true, the order among the facts is revealed. Therefore, **it is an organising principle.**

***For example :*** Before Newton discovered the theory of gravitation, there appeared to be no connection between facts like - freely falling objects, movements of planets, phenomena of tides. His theory of gravitation revealed the connection between these apparently unrelated facts and showed that they were all due to gravitation.

**(5) Result of rational activity :**

In order to solve the problem, hypothesis is suggested but no problem can be solved without rational thinking. **So, hypothesis is said to be the result of rational activity.**

**(6) Result of keen and creative imagination -**

Every hypothesis originates out of a problematic situation. However, to perceive and solve the problem is not easy. Hypothesis is the result of the scientist's keen and creative imagination.

***For example :*** In the year 1795, Nicolas Appert observed that Napoleon Bonapart regularly shipped food for his military. But the food would spoil by the time it reached its destination. Nicolas wondered about the why and how of this event. A thought came to his mind that if the food is boiled and sealed in a glass jar with a cork then it may not get spoilt. He conducted an experiment to test this hypothesis and found that the food did not get spoilt, as the germs in the food were killed by boiling the food and also outside germs could not enter the food as the glass jar was sealed with the cork.

**Inventor of the food preservation process (Canning)**

This hypothesis which resulted from Nicolas Appert's creative imagination lead to the invention of canned food.

## 7.4 Origin / suggestion of hypothesis :

Hypothesis is a tentative supposition that is formulated in order to solve the problem and to explain the related fact and phenomena. However, there are no rules that guide how to formulate a hypothesis. Study of various discoveries by scientist give us clues as to how hypotheses are suggested to scientist. Following are some important factors which may suggest hypothesis to scientist.

**(1) Keen and creative imagination :**

Investigators creative imagination is the mother at all inventions / discoveries. Every hypothesis has its source in imaginative mind of the scientist. This is the reason why common person cannot suggest a good hypothesis.

***For example :*** Every farmer must have observed apples falling on the ground but it was Newton's creative imagination which led to the discovery of the theory of gravitation.

**(2) Painstaking work :**

Though keen imagination is the most important factor of thinking of hypothesis,

along with it, painstaking work of scientist is also important. Without hardwork only with keen imagination rarely any discovery can take place in science. Scientist may have to work for months and years together to find a solution to the problem.

***For example :*** Kepler is said to have considered nineteen wrong hypothesises before he hit upon the right hypothesis that "planets revolve in elliptical orbits".

### (3) Adequate and wide knowledge :

It means that investigation and painstaking work must be backed by adequate knowledge of the subject in which the investigation is being done.

***For example :*** Diseases of silk worms

Louis Pasteur was the only scientist in France, who could cure the disease of the silk worm, as he had adequate knowledge of diseases in general, though he had no knowledge of silk worms.

### (4) Insight :

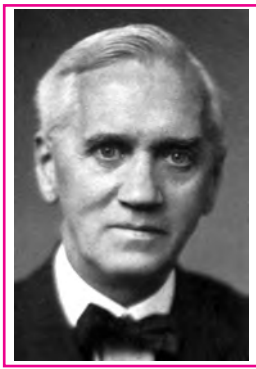
Scientist work hard to solve the problem but it may not always give a solution to the problem. Sometimes the right solution comes as a sudden flash of lightening called as insight.

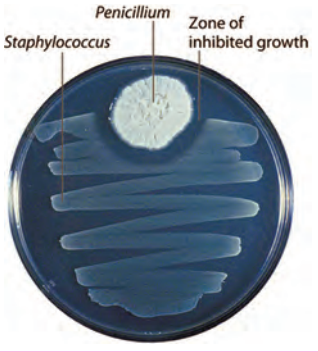
***For example :*** when Archemedes jumped into the tub containing water and observed that water was thus thrown out of the tub, he got the solution to his problem. He then framed a hypothesis that 'when a body is partially immersed in water, it loses weight and the loss of the weight of the body is equal to the water thrown out of the tub.' This hypothesis struck his mind as a sudden flash of insight.


### (5) Chance / Accident :

Chance too plays its part in suggesting a fruitful hypothesis. Some of the great discoveries take place due to the chance observations. However, great discoveries are never accidental. The so called accident is merely a chance observation which a scientist is able to use due to his specialised knowledge and creative imagination.

***For example :*** the discovery of penicillin by Alexander Fleming was the outcome of chance observation. In September 1928, before proceeding on week's vacation Alexander Fleming had started some germ cultures. On his return, he examined these cultures. He picked up one dish from the window ledge, and found that the culture had been spoiled. There were other bacterias in it. As he was about to throw it away he observed that, around a small patch of mould, there were no germs. **This suggested to his mind the hypothesis that the mould was giving out some substance which was preventing germs from growing in its neighbourhood.** That led to the discovery of penicillin.





Alexander Fleming could take advantage of the "chance" observation, because he had specialized knowledge about Lysozyme. (Lysozyme is a natural property by which germs are destroyed). Sir Alexander Fleming used to demonstrate that tears from the eye possess the property of lysozyme. He would, take in a test tube, a solution containing germs. Then he would take a tear from the eye and drop it in to the solution. Suddenly the solution would become clear. The germs were destroyed.

Alexander Fleming could understand why there were no germs around the mould, because he was familiar with lysozyme. So we see that a chance observation merely provides an opportunity of coming across the phenomenon. But a trained mind is required to understand the significance of the unexpected occurance.

### (6) Induction per simple enumeration and Analogy -

These are common mans methods of arriving at conclusion. Sometimes these conclusions may suggest hypothesis to scientist.

When a generalization is supported by positive instances and no contrary instance has been observed, the method of simple enumeration is said to be used.

An analogy is an inference in which the conclusion is drawn on the basis of observed resemblances.

***For example :*** Conclusion of Lowells's analogy of Earth and Mars, that there is life on Mars has become a hypothesis in science.

## 7.5 Conditions of good hypothesis :

Hypothesis is a guess work and need to be tested or verified only then it is accepted. But verifying each and every hypothesis becomes a laborous, time consuming and complicated process.

Hence, scientists do not verify each and every hypothesis. They select few hypotheses for further verification. **These selected few hypotheses are not true solution to the problem but they are the ones which the scientist think worth considering.**

**Such worth considering hypothesis is called a good hypothesis** and such good hypothesis are said to have scientific value. A hypothesis is considered to be good if it satisfies certain conditions as follows ...

### (1) Relevance :

A hypothesis must be relevant. The function of hypothesis is to explain the facts which have become a problem. It can serve this purpose only if the hypothesis is relevant to the problem.

A relevant hypothesis is one from which the facts to be explained can be deduced as a logical consequences. As per this definition when the hypothesis is proposed, one may not know whether it is relevant. Scientist may have to observe more facts to determine whether it is relevant. Therefore, the condition of relevance only means that in the light of specialised knowledge, the scientist genuinely believes that the hypothesis is relevant.

***For example :*** Hypothesis suggested by followers of Galen is a good example of irrelevant hypothesis. Galen theory suggested that human thigh bones are curved. Later Vasalius proved that human thigh bones are straight. He did this by dissecting human bodies which was not allowed at the time of Galen. One of the Galen's follower however could not accept this theory. So he suggested a hypothesis that, in natural conditions the bones are curved and the narrow trousers worn in those days were responsible for straightness of bones. It is very obvious that this hypothesis is irrelevant. These type of trousers have nothing to do with shape of bones.

### (2) Hypothesis must be self-consistent :

Hypothesis must not be inconsistent. There must be no contradiction among its differnt elements.

For example, the hypothesis of "living ghost" or that of "weightless matter" is inconsistent.

### (3) Hypothesis must be testable :

According to Irving Copi, the important condition of good hypothsis is testability or verifiability. One of the important conditions of scientific hypothesis. In order to confirm a hypothesis, it has to be verified.

***For example :*** A hypothesis related to ghost, evil etc. are now regarded as unscientific. They are not empirically verifiable. Thus a good hypothesis is said to be testable or verifiable. Hypothesis is verifiable means it is capable of being shown to be either true or false.

Verification is a process by which a hypothesis is confirmed. However there is no time limit within which a hypothesis is verified. So hypothesis should be verifiable in principle.

***For example :*** the ultimate destruction of life on Earth is a good hypothesis, it cannot be verified today. But it is verifiable in principle.

### (4) Hypothesis must be compatible with pre-established knowledge :

The goal of science is to establish a deductive system. One of the conditions of a system is consistency i.e. all laws included in a system must be compatible with one another.

If a new hypothesis is not compatible with established laws then it's chances of being true are very less. It is therefore said that a good hypothesis is one which is compatible with previously established laws. However sometimes it is also possible that the new hypothesis which is inconsistent with established laws turns out to be correct in that case the previously established law turns out to be incorrect.

***For example :*** The Copernicus system overthrew the Ptolemic system, even though the Ptolemic system was well established.

### (5) Hypothesis must have explanatory power :

A good hypothesis is not only capable of explaining those facts for which it is proposed but also can explain some more facts.

***For example :*** Newton's law of Gravitation not only explained the falling of an apple to the ground but also the planatory motions and phenomenon of tides.

### (6) Hypothesis must have predictive power :

If the researcher deduces more consequences from the hypothesis, then it is said that the hypothesis has greater predictive power. From this predictive power it becomes clear that a given hypothesis is not a scientists fancy of mind and is based on facts.

### (7) Hypothesis must be simple :

Scientist prefer the simpler of the rival hypothesises but they define simplicity in different ways. According to one view, **a simpler hypotheses is one which makes the minimum number of independent assumptions.** It explains facts without being vague, obscure, ambiguous and complex ideas. Sometimes, it so happens that the researcher has to choose from the rival hypothesis. In such a situation, he chooses the hypothesis on the basis of its simplicity.

Historically, the most important pair of such hypothesis were those of Ptolemy and Copernicus. Ptolemy put forth a theory that the earth is in the centre and the Sun and other planets revolve round the earth. On the other hand, Copernicus put forth a hypothesis that the Sun is in the centre and the earth and other planets revolve round the Sun. Both the hypotheses were equally good. The Copernican hypothesis was simpler than Ptolemic hypothesis and it was accepted, as it hardly made any number of independent assumptions

## 7.6 Verification of hypothesis -

A hypothesis is a tentative solution. When a hypothesis is formulated and known to be good, next step in scientific investigation is its verification.

Verification of a hypothesis consists in finding out whether it agrees with facts. If it agrees with the facts, it is confirmed. If it does not agree with facts, it may be rejected or modified.

**Kinds of Verification :**

There are two ways of verifying a hypothesis. These are Direct Verification and Indirect Verification. **Hypotheses that are verified directly are termed as empirical hypotheses or instantial hypothesis and those which are verified indirectly are termed as theoretical or non-instantial hypotheses.**

**(1) Direct Verification :**

It consists in observing the facts to which the hypothesis refers. Here we are appealing to facts directly. **Direct Verification may be either by observation or by experimentation.**

$H \longrightarrow F_1 F_2 F_3$

When actual observation shows that things referred in a hypothesis are actually found existing then it is called direct verification by observation.

***For example :*** Discovery of Neptune.

When hypothesis is verified by experiment in laboaratory, it is called direct verification by experimentation.

***For example :*** While explaining the phenomenon that "Nitrogen from air was heavier than Nitrogen from other sources", Rayleigh's hypothesis that "there may be some unknown gas present in air" was verified directly by performing an experiment. An unknown gas was isolated from Nitrogen obtained in the air. This gas was named Argon. The presence of this gas confirmed the hypothesis. Hence the hypothesis was accepted as it could explain why Nitrogen from air was heavier than Nitrogen from other sources.

**(2) Indirect verification :**

Most of the scientific hypotheses cannot be verified directly. **Such hypotheses are called non-instantial hypothesis. They can be verified indirectly.**

Indirect verification consist in deducing the consequences from a hypothesis and testing those consequences by appeal to facts.

Thus, two steps are involved in indirect verification -

(A) Deductive development of hypothesis - Deductive development of hypothesis means by assuming hypothesis as true certain consequences are deduced from the hypothesis.

(B) To find out whether the anticipated or predicted consequences take place. If the predictions come true, the hypothesis is said to be indirectly verified.

In indirect verification, the consequences are tested either by observation or by experiment.

***For example :*** Kon - Tiki Expedition

It was observed that there are certain similarities between the ancient customs of natives of South sea Islands and the inhabitants of South America, inspite of the distance between them. Some sociologists proposed the hypothesis that the natives of the South sea Islands came from South America.

This hypothesis cannot be verified directly so to verify it indirecly scientist deduced the consequences that, if it is true that the people travelled from South America to South sea island then they must have travelled by sea route using primitive kind of a boat.

This hypothesis was confirmed by conducting an experiment. Scientists undertook a trip in such a boat. The prevailing currents carried them to the destination. They arrived on the islands after a little over hundred days.

**Limits of verification -**

**Verification shows that "C" is the cause of "E" but does not show that "C" is the only cause of "E".** It shows that the hypothesis explains the observed fact quite well but does not show that it is the only explanation for the observed facts.

Most of the hypotheses are verified indirectly in science.

In direct verification there is hardly any doubt about truth of the hypotheses. But in indirect verification if hypothesis is accepted as true, our argument commits the fallacy of affirming the consequent as explained below :

If H is true then $C_1$, $C_2$, $C_3$ should take place

$C_1$, $C_2$, $C_3$ take place

$\therefore$ H is true

Indirect verification only shows that hypothesis may be true becuase it does not rule out the possibility that same consequences can take place due to some other reason, other than the hypothesis.

It is therefore necessary to prove the hypothesis. In proof of a hypothesis we attempt to show that the consequences can take place only due to the proposed hypothesis. The form of such an argument is as follows and it is not fallacious.

If and only if H, then $C_1$, $C_2$ , $C_3$ take place.

$C_1$, $C_2$, $C_3$ take place

$\therefore$ H

Thus proof of hypothesis consists in showing that no other hypothesis can explain the facts. In other words it is the only possible hypothesis which can explain the facts.


**Kon - Tiki Museum Oslo**