Types of Scientific Investigations

Scientific investigations are organized attempts to seek out, describe, explain, and predict natural phenomena. Scientific investigations are often performed to explore new phenomena, verify the results of previous investigations, test theoretical predictions, and discriminate between competing theories.

Choosing the Type of Investigation

There are many different types of scientific investigations that may be performed. The type of scientific investigation that is chosen depends on the question that is being asked in the investigation. Also, scientists sometimes combine aspects of more than one type of investigation.

Some investigations involve:

- collecting specimens
- seeking more information
- performing a field-based investigation
- performing a controlled scientific experiment
- making models

The type of scientific investigation that is chosen depends on the question to be answered, although it is possible for scientists to combine aspects of more than one type of investigation.

Collecting Specimens

Specimens are often collected when a scientist wants to compare and contrast different objects, such as rocks, or organisms, such as insects.

For example, a scientist might collect specimens of a particular kind of insect from many different locations. By documenting observations about the specimens, the scientist can precisely define several general aspects of the insect, such as its color, leg length, and head size, while also

comparing differences that may have developed within the species as a result of inhabiting different geographical locations.

Seeking More Information

 When new phenomena are observed, it may be necessary to seek more information. This is especially important in cases where the new phenomenon appears to refute well-accepted scientific principles.

For example, if someone claims to invent a machine that can boil water at less than 100°C, it might be necessary to seek more information about the conditions in which the machine is operating.

Performing a Field-based Investigation

 If an object or organism needs to be studied in its natural setting, a field-based investigation will be performed. Field-based investigations are often the best way to learn how things work in nature. It is important to tamper with a natural setting as little as possible when performing these investigations.

For example, if a scientist wants to investigate how gorillas behave in the wild, she must observe gorillas in their natural habitat and describe what she sees in a journal.

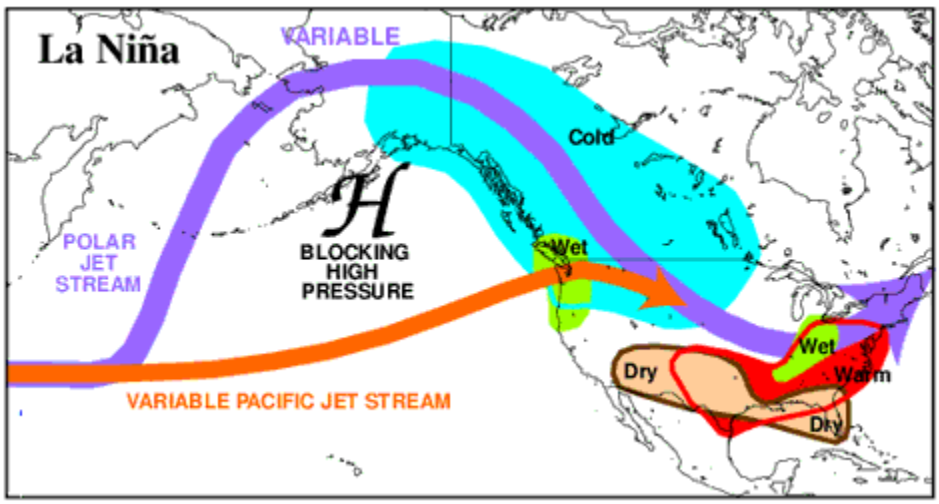
Performing a Controlled Scientific Experiment

If the conditions of an experiment must be very precise, or if an object or organism is not being studied in its natural setting, it may be beneficial to perform a laboratory experiment. Conditions can be controlled in a laboratory experiment.

In a controlled scientific experiment, there should be an independent variable, a dependent variable, and a control. The **independent variable** is the factor in the experiment that is manipulated by the researcher. The **dependent variable** is the factor in the experiment that changes in response to the independent variable. **Controls** in an experiment are used as comparison factors, and they can help determine the magnitude of the experiment's results.

Making Models

Making a model of something that is too large, rare, complex, or dangerous to fully observe in person can help scientists understand how it works.



For example, scientists might use a computer simulation program to predict weather patterns. By entering past and present weather conditions and phenomena, scientists can collect data from a large span of time and attempt to predict future weather patterns.

Scientific Investigations

Biologists ask many questions to help them understand living systems.

Some questions a biologist may ask:

- *When did life first evolve on Earth?*
- *Why do mitochondria resemble some species of bacteria?*
- *How do sea tortoises navigate?*

To answer these questions, biologists need to collect evidence through scientific investigations. Although the scientific method is not a fixed procedure, most scientific investigations have five basic steps:

Forming a Hypothesis

The questions that biologists ask typically come from observations of the natural world. To begin answering their questions, biologists form hypotheses. A **hypothesis** is a possible explanation for a set of observations or a possible answer to a scientific question. A hypothesis must be phrased in the form of a statement (rather than a question), and it must be testable. This means that scientists must be able to carry out investigations and gather evidence that will either support or disprove the hypothesis. Because hypotheses must be testable, the questions that biologists base their hypotheses on must also be testable.

Testing a Hypothesis

Scientist design **experiments** to test hypotheses. All factors that can change in an experiment are called **variables**. An experiment in which only one variable is changed at a time is called a **controlled experiment**. Because the variable in a controlled experiment differs between the control group and the experimental groups, scientists can be more certain that differences in the variable are causing any differences observed in the outcome of the experiment.

Data Collection

Gathering data requires observations to be made. Many observations involve the senses of sight, hearing, touch, and smell. Often, scientists also use tools that increase the power of their senses or make their observations more precise. Some tools commonly used by scientists include:

balance	a tool used to measure the mass of objects
graduated cylinder	a beaker marked in intervals that is used to measure volume
microscope	a tool used to produce magnified images of small objects
spring scale	a tool used to measure weight and force
thermometer	a tool used to measure temperature
test tube	a cylindrical tube, usually smaller than a beaker, that is open at one end and closed at the other

Interpreting Data

When an experiment is done, scientists analyze the data. Scientists use tables, charts, and graphs to organize, interpret, and present data. Organizing data in tables, charts, and graphs makes it easier to see patterns. Scientists analyze and interpret data tables and graphs to determine the relationship of one variable to another and to make predictions based on the data.

Communicating Results

After gathering and interpreting data, scientists draw conclusions about their hypotheses. Scientists then communicate the results of the experiment. This is an important part of any scientific investigation. Communicating results helps scientists learn from one another.

Observations vs. Inferences

***Inferences** are generalizations based on **observations**.*

Observations

Observations are made by making direct measurements or by using one of the five senses (touch, sight, taste, smell, hearing) to gather information from the outside world. Instruments, such as microscopes, balances and graduated cylinders, can be used to make observations. Measured observations can include the volume, length, and temperature of an object. Other observations, such as the color or shape of an object, can be made by using the senses.

A *scientific* observation is an observation that would be the same no matter who was observing it. For example, a measured observation that could be made about the beaker below is that it contains approximately 200 mL of liquid. An observation that could be made using only the senses is that the liquid in the beaker is purple.

An observation is *nonscientific* if it is based on an opinion. For instance, a nonscientific observation about the beaker above could be that the liquid in the beaker is a pretty shade of purple.

Direct observations are made by the researcher. The individual is present and witnesses the event, organism, or material that is being observed. **Indirect observations**, on the other hand, involve information obtained from another source, such as a survey or witness account. The researcher is not present throughout the observed occurrence.

Inferences

Inferences are conclusions that are made by studying observations. When scientists see patterns or trends in observations, they can make generalizations to summarize the patterns. These generalizations are known as inferences.

For example, suppose a scientist discovers a fossilized skeleton of an ancient organism that has never been studied before. The organism is large, and has long canine teeth and sharp incisors, much like the modern-day lion. The scientist could infer from these observations that the ancient organism was a carnivore.

Further Investigations

After completing an investigation, scientists often form new questions about the original subject.

New Questions

The new questions that result from previous research often build upon the knowledge that the scientist gained from the first investigation. Some possible new questions include:

- Can the investigation's procedure be improved to produce better results?
- Are there new investigations that should be performed based on the current results?
- What would happen if a different variable were tested? For instance, what if plants in an experiment were given different amounts of water or sunlight instead of different amounts of fertilizer?

The results from a study on the effect of fertilizer on plant growth might lead a scientist to then ask, "How does giving this kind of plant different amounts of water affect its growth?"

Sometimes, a conclusion cannot be reached from the data obtained during an investigation. Perhaps the data did not show any pattern or trend. In such cases, it is possible that more than one variable determines the result. To find out, the scientist should design a new investigation to show how a particular variable affects the outcome of the investigation.