Biology and the Experiment

1.07: What Is An Experiment? - Just Controlled Observations

It is the experiment that makes science so different from non scientific subjects. It is seen as the heart of the scientific method. A hypothesis is tested by an experiment. So what is an experiment? To put is very concisely you could say that *an experiment is controlled observations of an event which occurs naturally*. In other words, you set up an experiment to make more careful observations. These observations can then be used to make a new hypothesis or to prove an existing one.

It is more difficult to set up an experiment in biology or medicine than in physics or chemistry. This is because biology and medicine deal with living things and this can lead to ethical problems (see ethics at the end of this chapter). Also in biology and medicine it is not easy to control the variable you examine. Variables are explained later.

Are there different kinds of experiments?

There are two types of experiment:

The laboratory experiment and

The natural or observational experiment

Laboratory experiments

The laboratory experiment is carried out under fully controlled conditions in a laboratory. These experiments are similar to some you will carry out on your course.

Natural or Observational experiments

The observational experiment uses 'nature' directly as its laboratory. The scientist observes what happens in nature without much control over what is happening (often the scientist cannot control what is happening). Observational experiments are often carried out when something unusual happens in the natural world or if there is an accident. For example, if a new island is formed by a volcanic eruption, scientists may use the opportunity to observe how rocks are made or how the plants and animals colonise it (see ecology).

Mr. Morgan was famous in the 1930's for his laboratory experiments in genetics with fruit flies. He kept crossing the fruit flies to make observations that would prove Gregor Mendel's laws or segregation and independence. You will study these laws in the chapters on genetics.

One of the most famous nature experiments was that carried out by Charles Darwin when he sailed the world in the 1830's. He made thousands of observations about the types and kinds of plants and animals around the globe and then developed his theory of evolution by *natural selection*. His theory has been accepted today because it can be used to explain so much about the natural world.

Did you know?

The principle aim of scientific enquiry is to develop theories to explain the development and functions of the natural world and its existence.

Key Terms

DISPROVE
CONTROL EXPERIMENT
FALSE
GEOGRAPHICAL INFORMATION SYSTEMS
BIAS
SCIENTIFIC JOURNAL

Did you know?

Some scientists carry out *thought* experiments; they think about something. Philosophers have done this for thousands of years. A famous though experiment is called 'Schrodinger's Cat'. If you are interested in physics you might like to look up this thought experiment.

1.08: Does One Variable Make A Good Experiment?

Remember

A good experiment also requires a large sample. If the sample is too small the results may not represent the real situation in nature.

Yes, keep the number of variables to one if possible. Here is an example. Imagine the car will not start and you have to develop an experiment to find out what is causing it.

You hypothesise that the car is (i) out of petrol (ii) has a dead battery or (iii) the alternator is broken. Here you have three variables to examine: petrol, battery and alternator.

In order to find out which one it is, would you?

Experiment 1: change the battery and put some petrol in

Experiment 2: put in a new alternator and put some petrol in

Experiment 3: put in a new battery and a new alternator

Well I think you can see that even if the car started in either of these experiments, you still would not know why it would not start in the first place. The reason is, you were examining two variables at a time.

A good experiment is one that changes just one variable at a time. So to check the car you could try the following:

Experiment 1: add some petrol. Does it start? No, then try:

Experiment 2: add a new battery. Does it start? No, then try:

Experiment 3: add a new alternator. Does it start?

This way you eliminate one variable at a time.

An example in biology

Imagine that you know that the rate of photosynthesis is affected by changes in temperature, the supply of water, the speed of the wind and the amount of carbon dioxide in the air. There are four variables to consider here: temperature, water supply, wind speed, carbon dioxide levels. You want to set up an experiment to see the effect of temperature on the rate. It is important that you keep three of the variables constant and vary just one. In this case you would vary temperature while keeping the other three constant. You would then see the true effect of temperature changes.

Imagine if you changed both the temperature and the wind speed and the rate of photosynthesis increased. How could you tell whether the increase is due to the temperature or wind speed? You couldn't.

1.09: Fact: No Variables Change In A Control Experiment

A Control Experiment

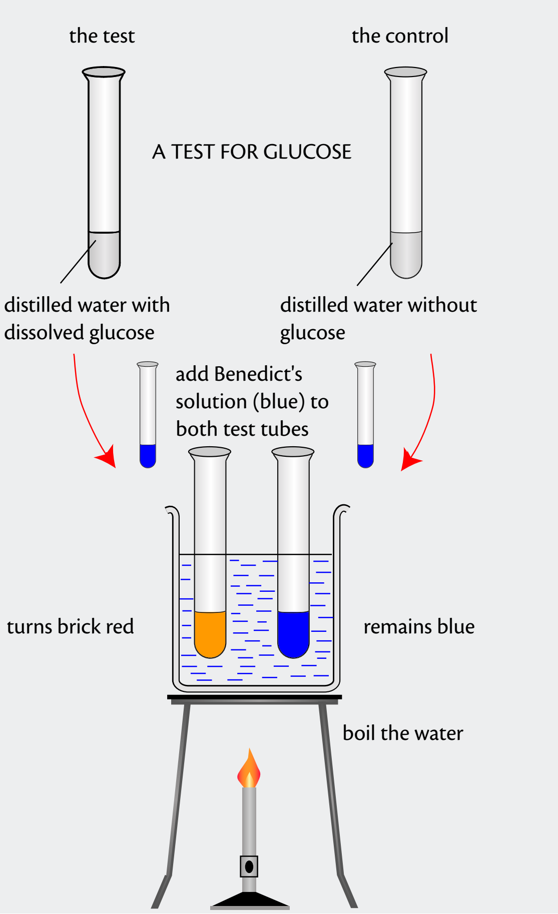
A *control experiment* is one in which the *independent* variable is removed. Remember the independent variable is the one you *vary* to test the hypothesis. If it cannot be directly removed from the control, then it is set to a standard value.

So an experiment must have a control. Sometimes this is not possible. For example, in the study of some feature of a volcano you cannot set up another volcano as a control. Nor can you set up a control experiment to prove the theory of evolution. What you have to do in cases like this is to continue making thousands of observations to try and disprove your hypothesis.

Remember

Without the control experiment you cannot be sure that the result you get is due to the single variable that you examine.

The control experiment verifies that the results you get are due to the one variable you are testing. In a controlled experiment the experimental (or independent) variable is also kept constant.



For example: The Food Test for Starch

Benedicts Solution turns brick red on contact with starch. The left test tube contains the glucose. This is what will be tested. The Bendicts Solution will turn brick red when added to the test tube.

The Control experiment is on the right. Everything is identical, except that there is *no glucose*. When the Benedict's solution is added it should not turn red indicating the absence of glucose.

How to Write out your Experiment

You must write clearly and honestly. Do not confuse people by being vague or complex. Use the following headings:

1. Aim: - State your hypothesis and what the experiment aims to show. Keep this section very short.
2. Method: - Write out clearly what you did so that another person can do the same thing (like writing out a cooking receipe). Use clearly labelled diagrams. Give all the measurements you use. Leave nothing out. If you had a difficulty, say so.
3. Result. - Write down what happened. Present any data you obtained in clear tables if possible.
4. Conclusion - Write down your conclusions and explain your results in the light of your hypothesis and say whether it supported it or not.

The Web: www.biology.ie has an animation of this investigation

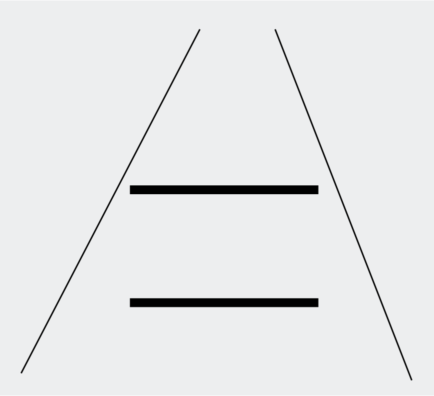
1.10: What Are The Five Principles of Experimentation?

All good experiments follow these five principles:

1. are carefully planned and designed
2. are carried out in a safe manner in a safe place
3. include a control experiment
4. are unbiased
5. are repeatable

1. Careful Planning and Design

It is often very difficult to design a really good experiment. It can take a scientist several months or years to design an experiment that shows a hypothesis is correct. It is not much good designing an experiment to show that the hypothesis is true; it must be designed to try and disprove the hypothesis. If you cannot disprove the hypothesis, other scientists are likely to accept it. If you only try to prove your hypothesis the chances are that another scientist will then design an experiment to show that you were wrong.



Which horizontal line is longer than the other, or are they both the same length?

It is easy to imagine that the top horizontal line is longer than the lower one. However, mesurement will confirm that they are both the same length. Measurement is important in science.

2. Safety

Safety in the laboratory must be considered at all stages of development. Your Laboratory Handbook describes in detail the safety procedures that must be taken.

3. Control Experiment

A good experiment should have a control experiment running at the same time if possible. See Control Experiment on the previous page.

4. Remove Bias as much as possible

A bias is a predjuice or an inclination to see a situation in one way only. It is difficult to make an observation without being biased. Think, for example, of the varied descriptions of a goal scored in a match or how much it rained last Wednesday! 'It was a brilliant goal' or 'it was a lucky shot'. To try and remove the bias from experiments scientists use the following methods

(a) Measurement

Here are some common instruments:

- Thermometers remove our bias about hot or cold objects.
- A measuring tape removes our bias about length.
- A protractor removes our bias about angles.

(b) Using a large sample size

If, for example, if your experiment involves testing a vaccination for TB on badgers, there is little point in testing it on just two badgers and then saying it is a success. A larger sample is needed to ensure that the vaccination is working on the whole population.

(c) Random Selection

When it is not possible to carry out a test on every individul species or individual in a test, you can take a random selection of individuals. The random selection must be made without bias. For example, if you want to select twenty flowers from a field, it is best to throw a quadrat (see Ecosystem) backwards over your shoulder and take the flowers within the quadrat.

YOU NOW KNOW?

Biologists solve problems in the living world using the scientific method as a tool to discover new knowledge.

(d) Double Blind Test

The purpose of this test is to (i) prevent bias (ii) prevent self deception and (iii) reduce errors in experiments. It works in a very simple way. Imagine that you have discovered a natural remedy called EYEBRIGHT that improves people's eye sight. To carry out a double blind test on 20 people you must do the following:

1. Make up pills with EYEBRIGHT and pills without EYEBRIGHT. All the pills must look identical.
2. Divide the pills into their two groups and give them to another scientist who does not know which ones contain the EYEBRIGHT and which ones don't. The ones that don't contain it are called the placebo pills.
3. Ask this scientist to give the placebos to 10 people and the EYEBRIGHT to the other 10 (remember the scientist does not know which ones are the placebo) and to monitor the effects they have.
4. Lastly, the scientist must return the results to you. After examining the data, look at who has taken the EYEBRIGHT.

It is important that the test is given by another scientist who monitors the results, even though he does not know who is getting the placebo. In this way the test can give a true indication as to how good the EYEBRIGHT is.

5. Repeatability

All experiments must be repeatable by either the scientist or more especially by other scientists. If an experiment cannot be recreated at least once more, then it is suspect and will probably not be accepted by other scientists as a valid experiment.

1.11: More About Data And Measurements

In the previous section you looked at methods for removing bias from the data collected. These methods included *measurement*, using a *large sample* and *random* selection. Here we will look at data collection in general. All biologists use standard instruments (such as microscopes) and techniques (such as plotting graphs). Some hypotheses can only be tested by the development of new instruments.

A bit about measurement

Data collection depends on measurement. Here are some examples important in biology.

The importance of time in biology

How long does it take a normal liver cell to divide: how long does it take a similar cancerous cell to divide? How long does it take for the egg of a sparrow hawk living in a city to hatch, compared to one living in a rural area? When do leaves fall off a tree? How fast can a snail travel one meter? Clocks are instruments used by humans to measure how long it takes for something to happen. Common man-made or artificial units are seconds, minutes, hours, days, weeks, months, years. We can use the idea of 'natural' time units such as night-time for nocturnal animals (cats, bats or badgers), or day-time/diurnal organisms (birds, bees). As organisms have used nature as their clock for millions of years we can talk about the new moon, quarter or full moon. Tides are controlled by the moon and sun and these in turn affect the plants and animals. All organisms depend on time for activities at some stage in their lives.

Instruments have been developed to measure how long a mammal can stay under water; how long it takes a fish to swim the width of an ocean; how long it takes an alien species to overrun an ecosystem.

What happens when you have the time data?

Time is often the variable that scientists examine in experiments. Time measurement (data) once collected, is then written up by the biologist into tables and sometimes the tables are used to create graphs. Graphs and tables can help us to see patterns or trends that are not easy to see in a list of data. In graphs time is usually placed on the horizontal axis.

Remember

All collected data must be labelled clearly and recorded into a book or computer. Biologists often use computer programs called spread-sheets to store their data. Instruments are used to collect data. Thermometers, rulers, weighing scales and protractors are all typical instruments used by biologists.

The importance of distance in biology

The question 'how far?' is answered using units such as kilometres, meters, centimetres and millimetres. For small objects, such as cells, biologists use micrometers. A micrometer is a 1000th part of a millimetre; or you might prefer to use 1 millionth part of a meter. The part of a seed that stores food may be just 100 micrometers in length. A single bacterium is about 1 micrometer in length; this means that a thousand would stretch end to end over a millimetre.

Scientists use micrometers to measure biomolecules. A biomolecule such as sugar is about 1/1000th of a micrometer. Atoms are so small that scientists use a smaller unit to talk about their sizes.

Definition

A micrometer is 1000th of a millimetre. A bacterium is about 1 micrometre. The tip of a pencil could hold about 1000 such bacteria.

Small distances like these can be used to measure the rate of growth of bacteria, or the number of cells in a given area of tissue.

Looking at very small things

Some things are too small to be seen by our eyes without help (the naked eye). It is impossible to see individual bacteria or blood cells with the naked eye. Magnifying lenses and microscopes allow us to see these tiny things by magnifying the *image* of the object (the object you are looking at is never made bigger). The number of times an image is magnified is given by a number such as 10x. This means that the image of the object is 10 times larger than could be seen with the naked eye. You will learn a bit more about microscopes in chapter 6. Some microscopes have rules with micrometers etched on them so you can see the length of things you are looking at.

Types of observations: quality and quantity

Biologists can make two types of observation; qualitative (about qualities) and quantitative (about quantities). Any instrument that can record changes can be used to collect data for qualitative or quantitative use.

What is the difference between these?

Quantitative observations are those that can be written down as quantities; so measuring the length of a bacterium is a quantitative observation. Counting the number of fish that move up a river is a quantitative observation.

Qualitative observations are those that use the qualities of things. For example, a botanist might say that the flowers are white; a zoologist might observe that the reptiles were the first to leave when it became colder. An ecologist might record his observation by writing 'the rats are destroying the ecosystem'.

Familiar instruments used for qualitative and quantitative observations are: **Cameras**: video cameras, digital still cameras; small cameras on microscopes or hidden on animals. **pH meters**: for measuring how acidic a liquid is. **Thermometers** for measuring temperature.

Computer software is used to collect data, analyse data and create models of how things work. pH meters can be attached to computers and automatically draw graphs of the collected data.

Questions - Now Its Your Turn

Q 01. What is an experiment? Name two different types of experiment. Which type would you like to work with if you were a biologist? Why?

Q 02. When a scientist sets up a situation where he/she is carrying out 'controlled observations', what stage of the scientific method are they involved in? Write a short note on controlled observations.

Q 03. Why can some experiments not be carried out in a laboratory?

Q 04. What is a variable. Name one type of variable used in experiments. Can scientists always control the variables they use in experiments?

Q 05. Name the essential feature of a good experiment. Explain you answer with an example.

Q 06. What is the purpose of a control in a scientific experiment. Explain your answer with an example.