**Learning outcomes**

|  |  |  |
| --- | --- | --- |
| At the end of this section you should be should be able to: |  |  |
| * Describe the process of the scientific method |  |  |
| * Outline the limitations of the value of the scientific method |  |  |

**1.1.3 Experimentation**

|  |
| --- |
| At the end of this sub section you should be able to: …… |
| State the principles of experimentation – which include:  Planning & Design, Safety Procedures and Experimental Control, |
| Explain why:  Sample Size, Random Selection, Replicates and Double-Blind Testing are important |

**Key words**

**The scientific method, Hypothesis, Control, Data, Replicate, Theory, Principle, Double blind test, Bias, Placebo**

**Process of the Scientific Method**

**Observation**

**Hypothesis**

**Experiment**

**Result**

**Conclusion**

If hypothesis is supported

Formation of

**Theory** which over time can become a **Principle**

If hypothesis is not supported

A new hypothesis needs to be found and tested

COLLECT DATA

INTERPRET DATA

**Definitions (Key words)**

**The scientific method** : A series of steps used to help solve a problem or answer a question

**Hypothesis:** An educated guess/ a possible explanation for an observation

**Control:** Set up for comparison with experiment

**Data**: Measurements/ Observations/ Information gathered during an experiment

**Replicate:** A repeat of an experiment

**Theory**: A supported hypothesis

**Principle:** a theory which has stood the test of time and is shown to be valid under all conditions.

**Double blind test** : Neither researcher nor group know who is receiving the active ingredient. Avoids bias.

**Bias:** Researcher influences the result to favour a particular outcome

**Placebo:** A substance without an active ingredient. Sometimes patients given a placebo treatment will have a perceived or actual improvement in a medical condition. This is known as the placebo effect.

**Limitations to the Scientific Method**

* **The extent of our basic knowledge**

A basic amount of knowledge is required if the correct questions and hypotheses are to be formed.

* **The basis of investigation**

Investigations must be carefully and properly designed or the validity of the results will be called into question.

* **Our ability to interpret results**

Human error or bias on the part of the researcher can lead to incorrect interpretation of results.

* **The natural world in a state of change**

Theories and hypotheses often do not stand the test of time as new knowledge becomes available and living things are in a constant state of change.

* **Accidental discovery**

e.g. discovery of DNA profiling

discovery of antiboitics

**Note**

* The Scientific Method cannot prove the truth it can only prove that ideas are false. No explanation is 100% certain e.g. better instruments, or a chance discovery, or new information or a new idea could overturn the old hypothesis.
* Scientists constantly challenge each others work and conclusions and scientific theory changes as knowledge increases. Scientists have to be prepared to defend their work and their explanations in public. This is done in scientific journals e.g. Nature, at conferences and on the internet.
* The observations, hypotheses and experiments are documented in accessible sources where all can examine them. These results are expected to be repeatable, that is, to be obtained by anyone following the same procedure.

1. Answer the following, which relate to the scientific method, by completing the blank spaces.

(a) As a result of her observations a scientist may formulate a ……………………………………… She will then progress her investigation by devising a series of ……………… and then carefully analysing the resulting ………………………

(b) Why is a control especially important in biological investigations? …………………………………………………………………………………………………..

(c) If a scientist wished to determine the effect of a certain herbicide on weed growth she would include a control in the investigation. Suggest a suitable control in this case.

………………………………...……………………………………………………………

(d) The use of replicates is an important aspect of scientific research. What, in this context, are replicates? …………………….…………………………………………………………………..

……………………………………………………………………………………………

(e) Suggest where a scientist may publish the results of her investigations

……………………………………………………………………………………………………

**Example of an experimental design**

|  |  |
| --- | --- |
| plants_miracle | **Hypothesis:** Plants will grow taller when given Miracle Grow.  Plants A & B are both given the same amount of light, water, and are stored at the same temperature. Plant A is given Miracle Grow.  All the **variables** are kept constant except the one you are testing. |

**Independent Variable** - the factor you change, what you do to your exp. group. (Miracle Grow)  
**Dependent Variable** - what happens as a result of that treatment, what you are measuring (height of plant)

**Collecting Data**

A scientist carefully collects and organizes data from the experiment. Data should always be presented in a neat fashion, usually tables or graphs.

**Data can be displayed as a graph**

**Data Table Example**

|  |  |
| --- | --- |
| plant_data | plants_graph |

|  |  |
| --- | --- |
| Smithers thinks that a special juice will increase the productivity of workers. He creates two groups of 50 workers each and assigns each group the same task (in this case, they're supposed to smithers2staple a set of papers). Group A is given the special juice to drink while they work. Group B is not given the special juice. After an hour, Smithers counts how many stacks of papers each group has made. Group A made 1,587 stacks, Group B made 2,113 stacks. | What was the initial hypothesis?  How was the hypothesis tested?  Identify the Control Group  Are there flaws in this research? What are they?  How could this experiment be improved? |

**EXPERIMENTATION**

**Planning and design:**

What is the purpose of the investigation? How can you make sure it is a fair test? What controls are needed? What equipment is required? How many times is the procedure to be repeated? How are results going to be recorded and presented? Be careful not to cause suffering to animals. In most hypotheses there are a number of factors which may influence the result. These are called variables.

**Variables**

In most experiments, only a single factor or variable is tested. All other variables should be kept constant.

**Independent Variable** - the factor you change, what you do to your exp. group.   
**Dependent Variable** - what happens as a result of that treatment, what you are measuring

**Safety:**

All safety procedures pertaining to lab work / field work should be adhered to.

**Control**: A control experiment should be used to provide a comparison against which the actual experiment can be judged. In carrying out experiments, all conditions should be kept constant except the one being tested. This is known as the experimental variable. To be absolutely sure that the results are due to the experimental variable and not to some unknown factor, it is necessary to set up a separate sample known as a control group. A control group goes through all the steps of the experiment except the one being tested.

**Sample size**: When carrying out an experiment it is important that more than sample is tested. Normally as large a sample as possible is tested. This reduces the risk that the results are due to individual differences, rather than being caused by the factor being investigated.

**Random Selection**: The organisms for the experiment must be selected at random and not selected as the best ones to get the expected results.

**Replicates**: Repeating an experiment many times helps to verify results and prevents jumping to conclusions based on a single set of results. Refers to the number of times you repeat your entire experimental design including controls.

**Double blind testing:** In a properly designed experiment neither the researcher nor the person being tested should know who is receiving the real treatment and who is receiving the placebo. This ensures avoiding bias in an experiment.

**WAKEFIELD EXPERIMENT as an example of poor research – scientific method not followed**

In 1998 Dr Andrew Wakefield conducted research which suggested a link between the MMR vaccine and developing autism- bowel syndrome. The results of his research was published in a reputable scientific journal The Lancet and has been one of the biggest health controversies resulting in large groups of parents opting not to vaccinate their children against measles, mumps and rubella.

Medical and scientific experts and recent research suggests that the research carried out by Wakefield were significantly flawed.

* There was no research hypothesis clearly stated.
* Sample was highly selective – 12 children who had been selected because they had both bowel symptoms and autism like syndrome.
* Sample extremely small – sample size should be 100’s if not 1000’s
* No control group – a group of individuals who had never been exposed to the vaccine
* Parental recall – the alleged link with MMR vaccine was based on parental recall, parents were asked to consider how closely in time the vaccine was with the on set of autism like symptoms. The study took no steps to prevent recall bias i.e. remembering a closer association between two events than actually occurred. The notion that children were normal one day and showed clear signs of autism the next day is scientifically implausible.
* No double blind testing – the researchers who examined the children and analysed the samples all knew that the children had received MMR and that a link had been raised about its link with with autism bowel syndrome.
* Conflict of interest- As well as carrying out research on whether there was a link between the MMR vaccine and autism he was also being paid to acrry out a study for the Legal Aid Board representing parents who believed the vaccine caused autism in their children and intended suing if as soon as such proof was found.

