Chapter 1: Science Inquiry Skills

Investigations

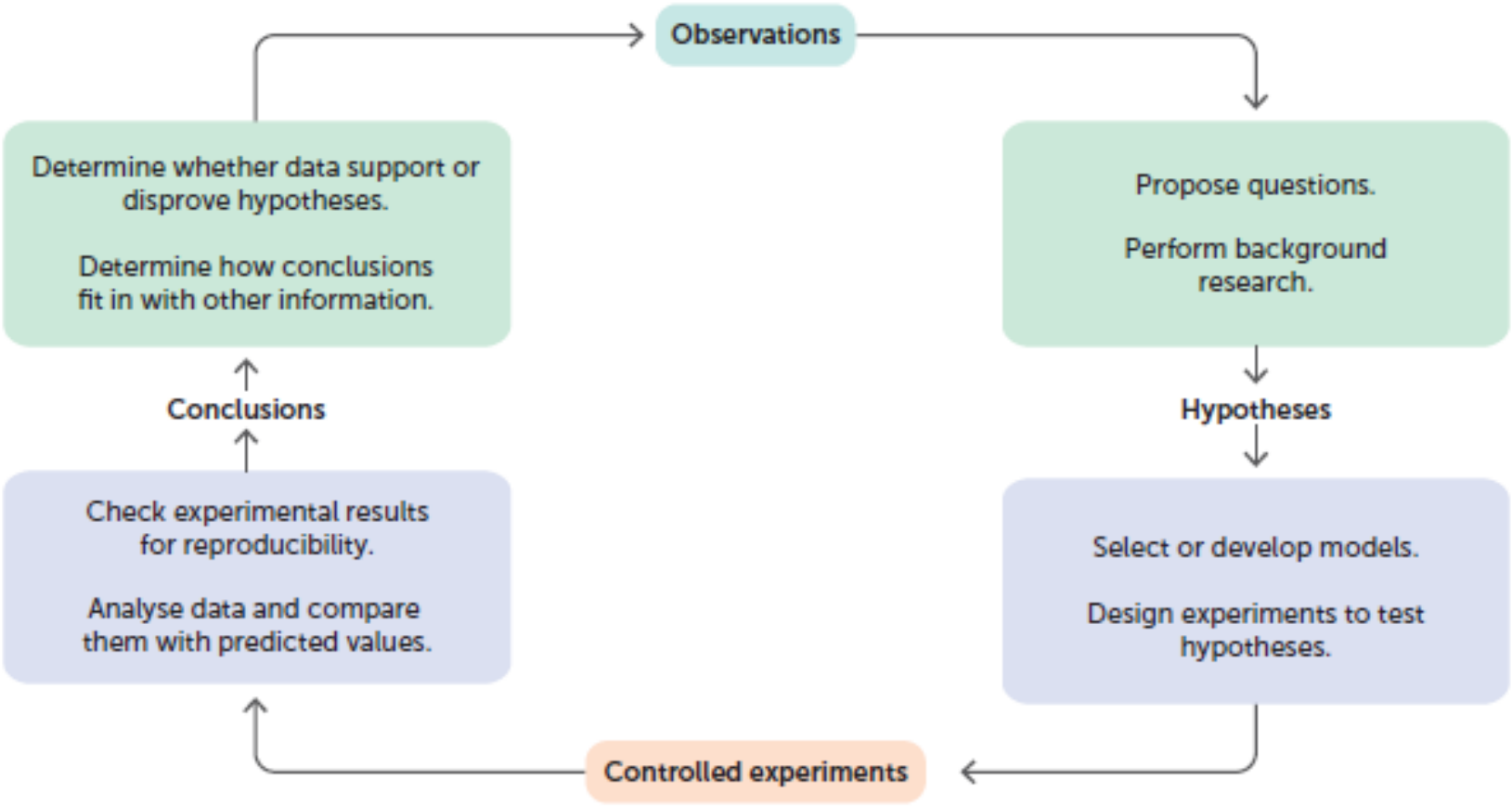
Permission given by Samantha Setterfield, UWA Professor

Researchers using quadrats to measure aquatic plant populations on the tropical floodplains of Kakadu National Park (NT). The researchers were measuring the impact on native plant populations of an invasive grassy weed called Para grass. All measurements have to be done from air boats because normal boats cannot get through the dense vegetation.

Investigations use a scientific process to answer a question, explore an idea or solve a problem.

The process of systematic observation and experimentation; formation and testing of hypotheses is known as the **scientific method**.

The scientific method



The scientific method

Hypothesis
A scientific statement, based on the available information, that can be tested by experimentation.
It can be thought of as 'an educated prediction'.
It should describe an expected relationship between the independent and dependent variables.
Examples:

If a new fertiliser is applied to a plant, then the rate of root growth will increase

If vaccinations for influenza increase in a population, then the number of hospitalisations will decrease

As the amount of licked surface area of a kangaroo's foreleg increases, then the rate of evaporative cooling increases.

Variables

A **variable** is a factor that can change. There may be several factors that can cause change in a particular variable. There are several different types of variable used during an experiment.

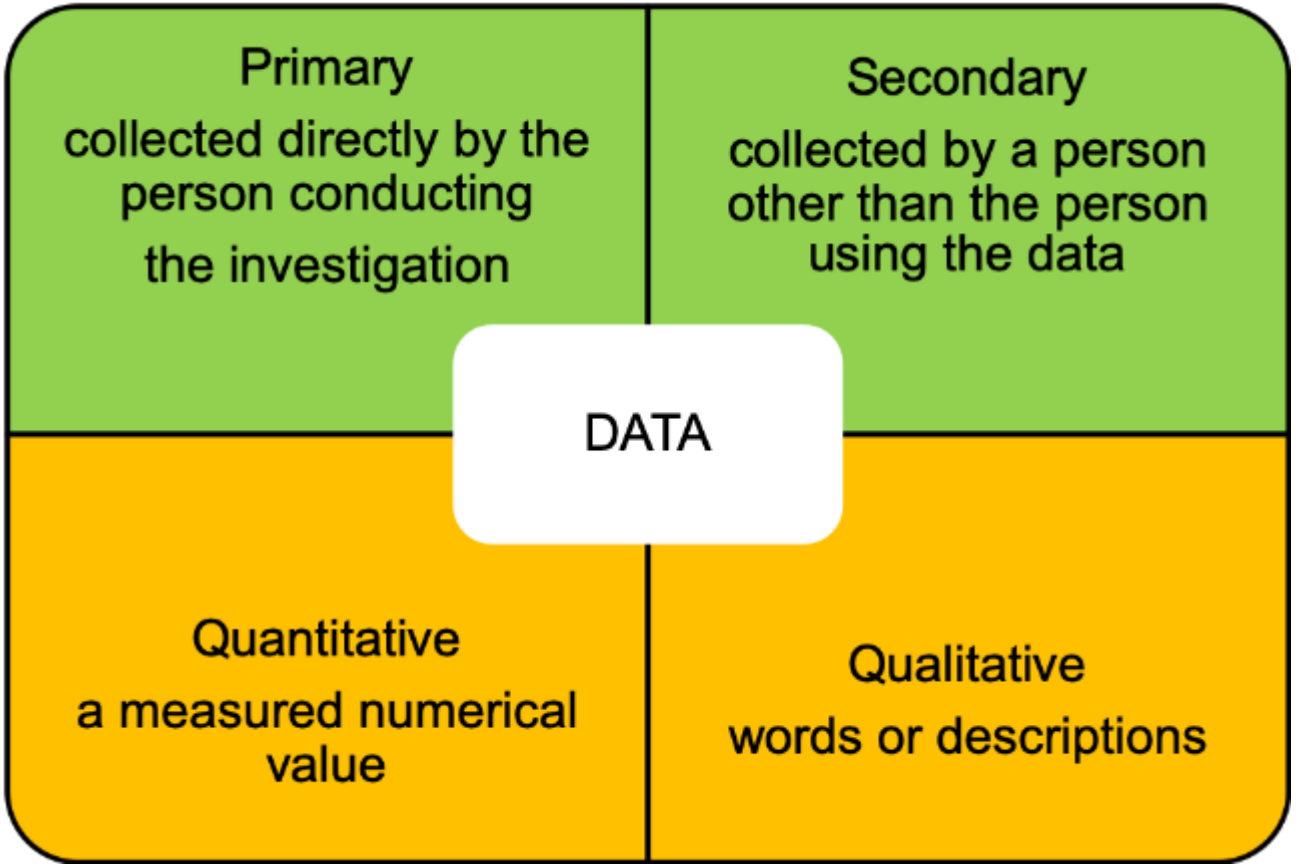
Independent variable: A variable intentionally varied by an experimenter to see what the outcome will be for another variable (the 'dependent variable').

Dependent variable: A variable that changes as a result of changes to the independent variable.

Controlled variable: A variable that is controlled by the experimenter and kept constant during the experiment.

The scientific method

Data



Safety - assessing risk

1. What are the possible risks to you, to other people, to property and to the environment?
2. How likely is it that there will be an injury or damage?
3. If there is an injury or damage, how serious are the consequences likely to be?

Animal ethics

iStock.com/Maksym Panchuk

Activities that impact on living organisms need to comply with the Australian Code for the Care and Use of Animals for Scientific Purposes. The main thrust of ethics is treating animals, other people and the environment with care and respect. The welfare of animals used for the purposes of research is legislated by state and federal laws.

Animal ethics

When using animals for research, scientists must adhere to the '3Rs'.

Reduction

Refinement

Replacement

The 3Rs of animal ethics

Reduction alternatives: methods that obtain comparable levels of information from the use of fewer animals in scientific procedures, or more information from the same number of animals.

Refinement alternatives: methods that alleviate or minimise potential pain and distress, and enhance animal wellbeing.

Replacement alternatives: methods that permit the given purpose of an activity or project to be achieved without the use of animals or with the use of non-sentient animals (those that lack a nervous system.

Animal models

A model can be used to test outcomes that might be expected in the real world, e.g. an animal that has a similar immune response to humans can be used to test a vaccine.

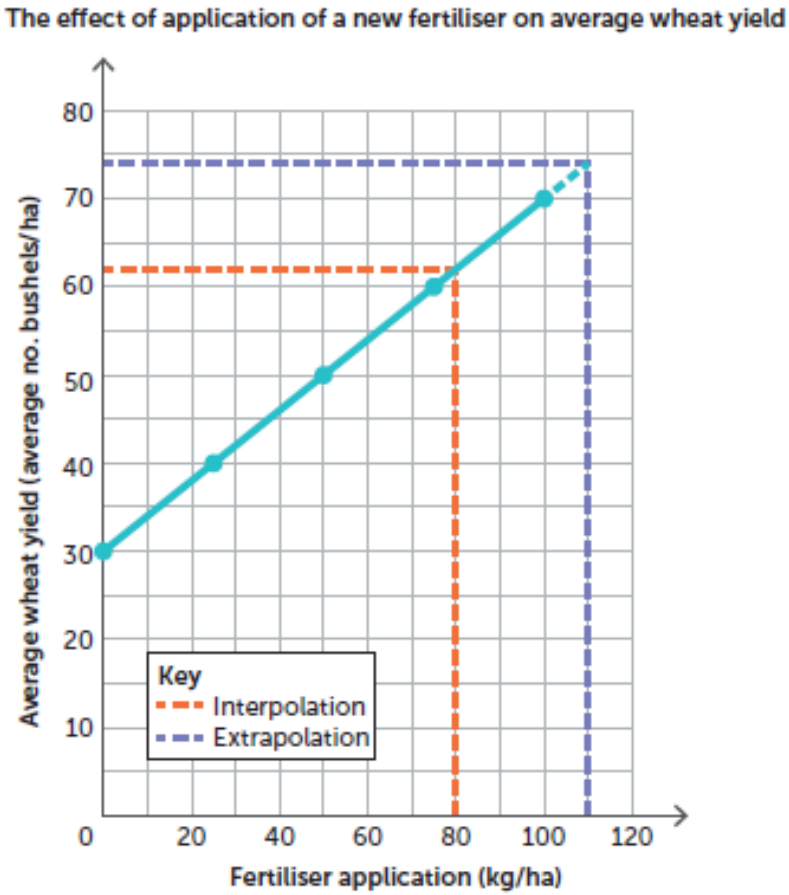
Table of results

Label the columns in the table with the name and units of the variables.
Do not put the units in the table cells.
The first column usually contains the measurements for independent variable.

FERTILISER APPLICATION (kg/ha)	TRIAL 1 YIELD (bushels/ha)	TRIAL 2 YIELD (bushels/ha)	AVERAGE YIELD (bushels/ha)
0	29	31	30
25	40	42	41
50	51	49	50
75	60	58	59
100	70	70	70

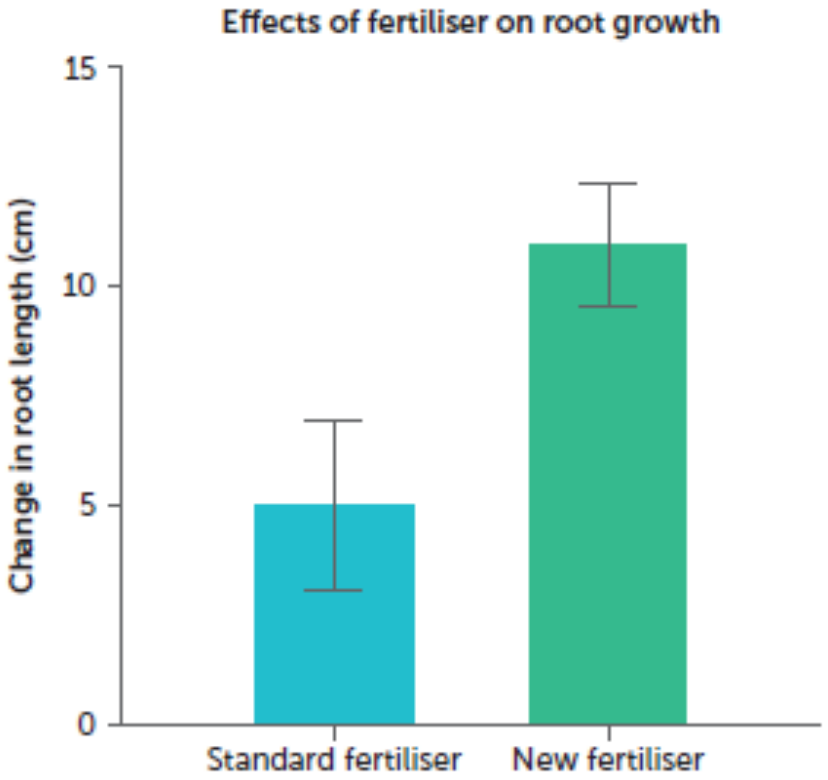
Graphing

Choose the correct graph by analysing the type of data. Continuous data will usually be displayed as a line graph.



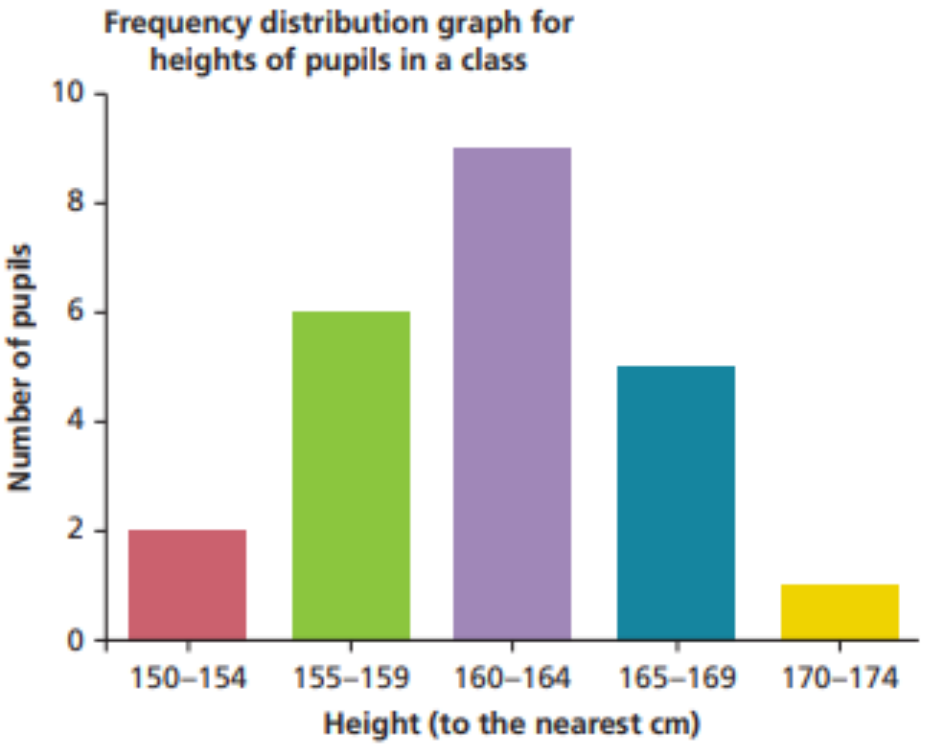
Graphing

Discrete data will usually be displayed as a column graph.



Graphing

A histogram may be suitable if your independent variable can be organised into sets of ranges of values such as human height. The dependent variable on the *y*-axis is the sum of the individuals in each range of values.



Conclusion

The conclusion is a very brief summary of the results and their implications. Say what you found out and what it means.

A conclusion should only be a few sentences long. It should include a response to your research question and to your hypothesis.

The paragraph should include supportive data from the results observed or measured.

For example:

The mean resting breathing rate was 18 breaths per minute compared with 25 breaths per minute after 10 minutes of exercise. The results supported the hypothesis. An increase in exercise caused an increase in breathing rate.

References

A references list acknowledges the sources you used, which avoids plagiarism and strengthens your arguments. APA referencing is commonly used in science reports.

For example:

Tian M, Castillo TL (2016) Solar heating uptake in Australia: rates, causes and effects. Energy

Efficiency Reports. Report no. 10, The Department of Sustainability and Environment, Canberra.

ABCNews. (2003) $250 m funding boost for malaria vaccine. Retrieved from https://www.abc.net.

au/news/2003-09-22/250m-funding-boost-for-malaria-vaccine/

Discussion

Reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute and achieves similar results for the same population.

When you repeat an experiment and get the same results, the data are considered reliable.

Reliable data can be obtained by repetition and replication if the method is valid and good experimental technique is used. **Repetition** involves multiple trials within the same investigation or using a large sample size.

Replication is the same investigation being conducted several times, possibly by more than one investigator. An average (mean) can often be calculated from the quantitative results obtained by both repetition and/or replication. This can reduce anomalous data/outliers.

An **outlier** is a data point that does not fit the pattern shown by other measured data points.

Discussion

Validity is the extent to which tests measure what was intended.

Valid data can be achieved by identifying the variables that should be controlled and then controlling them. It can also be gained by the use of a control group.

A **control** refers to a standard or group that is the same as the experimental group but for which the independent variable does not vary.

The purpose of the control group is to ascertain that the cause of any change in the experimental group is due to change in the one independent variable.

Discussion

Accuracy is the extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty.

It is the degree of closeness of a measurement of a quantity to its actual true value.

Accuracy can be improved through the use of more appropriate tools and techniques.

Discussion

Measurement error is the difference between the experimental result and its true value.

Systematic error, mistakes and random error can all contribute to measurement error. Systematic error is error that is due to failure to zero an instrument, or to a systematic flaw in the equipment or procedure. Reading an instrument from a consistent but non-90° angle can produce this type of error.

A potometer may leak water and indicate a higher rate of transpiration (evaporative water loss) than is correct. If a student consistently reads the volume of a liquid at the same but wrong part of the meniscus, there will be systematic error.

Communicating results

Examples of scientific presentation formats

Multimedia presentations
- PowerPoint®
- Canva®

Oral presentations
- Informative
- Persuasive

Journal articles
- Research
- Case study

Ecosystem survey techniques

Rationale

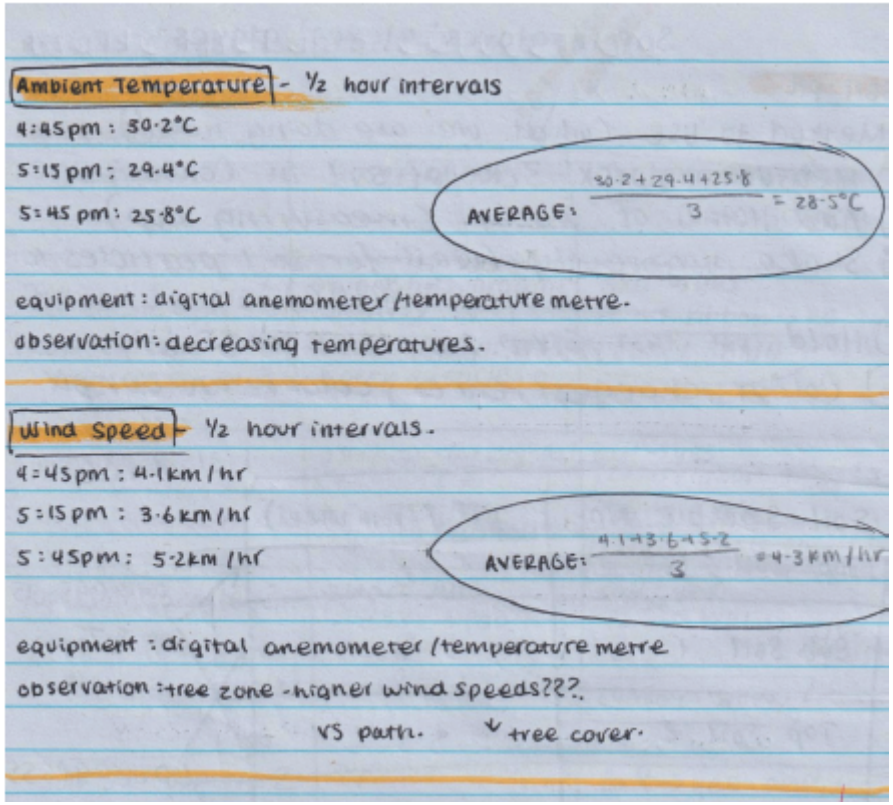
AAP Photo/WWF Australia

The Kangaroo Island dunnart is believed to be among the species worst affected by the 2019–20 bushfires. The Department of Agriculture, Water and the Environment has identified more than 100 species that had more than half their habitat in fire zones, leaving many at risk of extinction.

Australia has many types of terrestrial and aquatic ecosystems with high biodiversity. High biodiversity is helpful to humans for many reasons, such as providing medicine, food and clean water. Scientists aim to monitor and conserve biodiversity to preserve the resources that biodiversity provides.

Ecosystem survey techniques

Logbooks



Exemplar of part of a logbook produced by students on a Year 11 field trip

When scientists conduct research in the field, they record their raw data in a logbook or a device.

The logbook is used as evidence of the gathering of primary data and thoughts and strategies as they unfold.

Make an entry in the logbook every time you work on your investigation. At the start of each session you should record the date and the names of all the people with whom you are working at the time.

Population sampling techniques

Taking accurate measurements in the field relies on measuring a sufficiently large, representative sample of the population. Various standardised techniques have been developed to accurately sample populations and ecosystems.

Photographer: Michael Douglas, UWA; permission given Samantha Setterfield

University of Western Australia researcher Dr Leah Beesley measures river habitat and uses a GPS to locate nets as part of a study of fish populations in the Fitzroy River, WA. Researchers are trying to understand how fish populations change in response to different water levels in the river, which might result if water is used for agriculture.

Population sampling techniques

Photographer: Michael Douglas, UWA

A drone is used to take aerial photographs to measure plant populations in Kakadu National Park, Northern Territory. Researchers and traditional owners are investigating how plant populations change in response to different patterns of burning. Photographs are taken at different times of year and compared to see how the cover of trees and shrubs changes over time.

Population sampling techniques

Photographer: Michael Douglas, UWA

Jawoyn traditional owner Ryan Barrowei and CSIRO researcher Justin Perry control a drone to measure plant populations in Kakadu National Park. Researchers and traditional owners are investigating temporal changes (changes over time) in plant populations.

Ecosystem survey techniques

Quadrats

A quadrat is a square, rectangular or circular frame of convenient size, used to mark out an area in which the vegetation is sampled. Organism size and distribution should be considered before deciding on the quadrat size

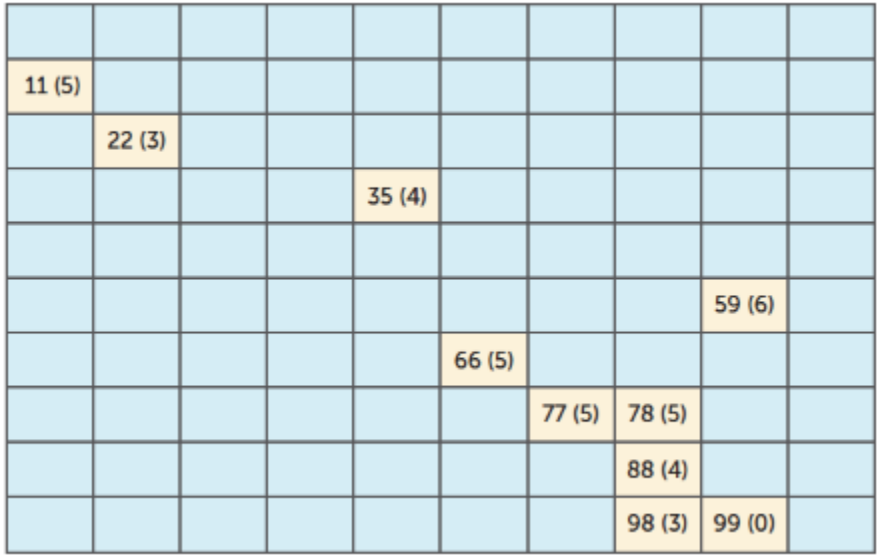
Steps

1. Randomly select the quadrats to use for counting.
2. Mark the selected quadrats and record the data in a logbook.
3. Add the total individual shrubs in the (e.g. 10) quadrats.
4. Divide the total by 10 to calculate the average per quadrat.
5. Multiply this number by (e.g. 100) to estimate the population in the area.
6. To calculate the population density, divide the number by 10. The answer will be the population number per unit squared.

Ecosystem survey techniques

Quadrats

For this example, a random number generator produced the numbers 11, 22, 35, 59, 66, 77, 78, 88, 98, 99. The number of shrubs in each of these quadrats is recorded in Figure 1.13. The quadrat number is written first and the population for that quadrat is recorded in brackets.



To investigate the distribution of shrubs in an area of 100 m^2 , 10 quadrats were randomly chosen and the number of shrubs in each was counted (shown in brackets).

Transects

A transect is a line through a large area of study, selected to include most of the plant and immobile animal groups present, and used to investigate changes in community composition and population abundance along an axis.

Jawoyn traditional owner Bessie Coleman and University of Western Australia researcher Samantha Setterfield use transects to measure wattle tree populations in Kakadu National Park. Researchers and traditional owners are investigating how plant populations change in response to different patterns of burning.

Electrofishing

University of Western Australia researchers Dr Leah Beesley and Chris Keogh use electrofishing to measure fish populations in the Fitzroy River, WA.

Microscopy

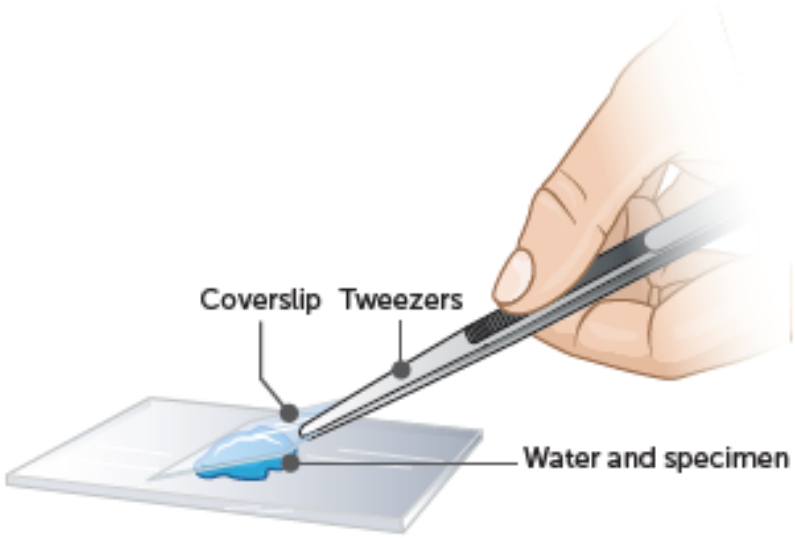
Microscopes magnify objects that may not be visible to the naked eye. The use of a microscope to view cells or objects that cannot normally be seen is called microscopy.

The resolution of a microscope is the smallest distance by which two points can be separated and still be distinguished as separate objects.

Magnification is the scaled enlargement of an object. As an object is magnified, resolution may decrease.

Making a temporary wet mount

Wet mount a glass slide holding a specimen that is suspended in a drop of liquid (such as water) for examination under a microscope



How to lower a coverslip to avoid the formation of air bubbles

Dissections

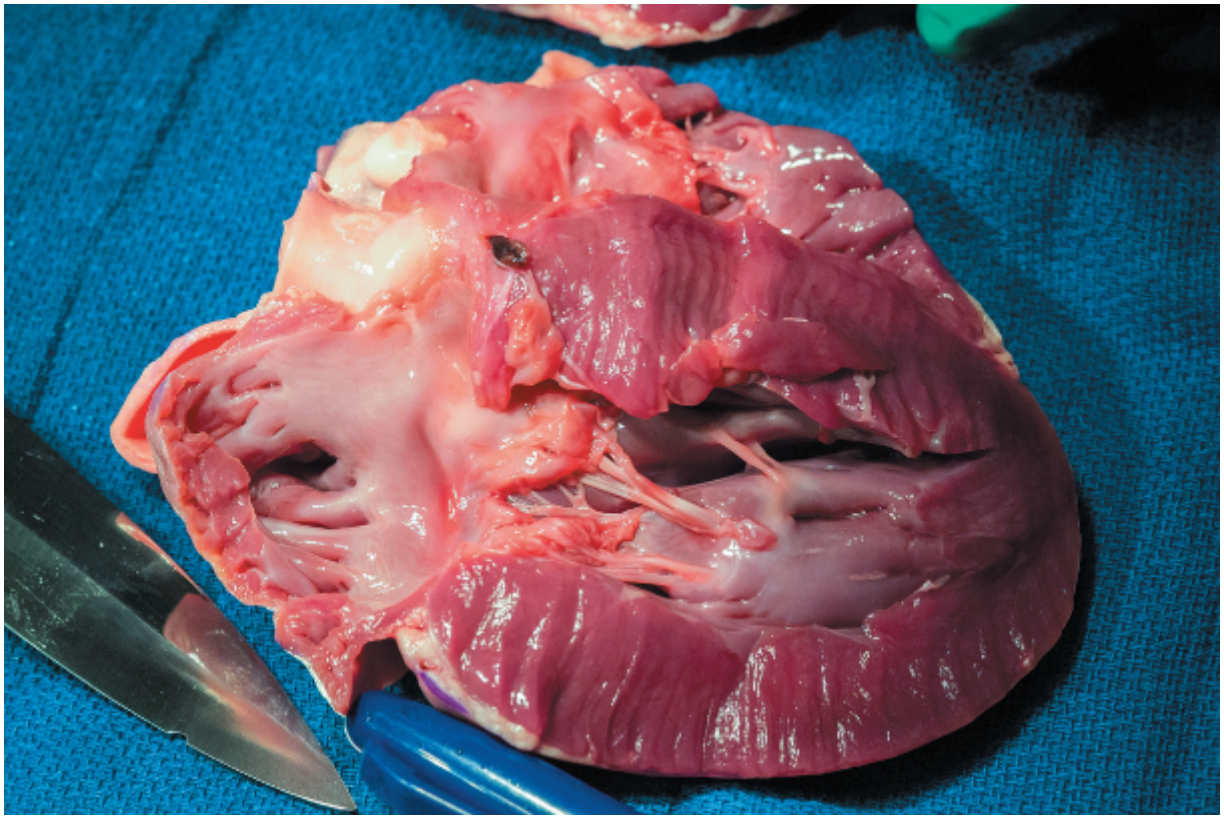
The process of carefully cutting open and exposing the interior parts of a plant or animal for study purposes is called dissection.

Keep in mind safety and animal ethics; the 3Rs.

Dissection tools

TOOL	FUNCTION
Scissors	Cutting apart tissues including bone
Forceps (large tweezers)	Holding sample while cutting tissue
Mounted needle	Holding the specimen (organism being studied) in place
Scalpel (handle with a blade)	Making incisions
Dissection pins	Securing parts of a specimen to a board

Dissections



Science Photo Library/Dr Barry Slaven

Standard dissection tools

Shutterstock.com/Tai Dundua