# *How To Do Science*

**REVISED EDITION**

LOUISE LEXIS AND BRIANNA JULIEN

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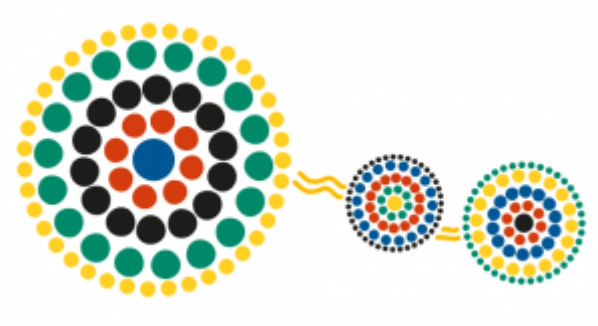
# *Contents*

# *Acknowledgment of Country*

The University of Southern Queensland acknowledges the traditional custodians of the lands and waterways where the University is located. Further, we acknowledge the cultural diversity of Aboriginal and Torres Strait Islander peoples and pay respect to Elders past, present, and future.

We celebrate the continuous living cultures of First Australians and acknowledge the important contributions Aboriginal and Torres Strait Islander people have and continue to make in Australian society.

The University respects and acknowledges our Aboriginal and Torres Strait Islander students, staff, Elders, and visitors who come from many nations.



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    - all content can be navigated using a keyboard
    - links, headings, and tables are formatted to work with screen readers
    - images have alt text
- Information is not conveyed by colour alone.

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# *About the Authors*

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**Dr Louise Lexis** is an Associate Professor (Teaching Focused) of human physiology at La Trobe University in the School of Agriculture, Biomedicine and Environment. Louise has taught human physiology at the undergraduate level for over two decades, and conducts research that investigates the impact of authentic scientific curricula on student learning and experience. She is a Senior Fellow of the UK's Higher Education Academy, and has a Graduate Certificate in Higher Education.

## DR BRIANNA JULIEN

**Dr Brianna Julien** is a Senior Lecturer (Teaching Focused) in human physiology at La Trobe University in the School of Agriculture, Biomedicine and Environment, and has taught human physiology to 1st, 2nd and 3rd Year students for 17 years. Brianna has a PhD in neurophysiology and a Graduate Certificate in Higher Education. The quality and impact of Brianna's work is recognised through multiple teaching awards up to national level and award of Senior Fellowship of the UK's Higher Education Academy. Brianna conducts and publishes education research that investigates the impact of authentic scientific curricula on student learning and experience.

Louise and Brianna are long-standing collaborators in learning and teaching, including teaching, curriculum development, and education research. Their partnership is built on shared commitment to providing students with the best possible opportunities to gain up-to-date physiology knowledge while also developing their research and communication skills, thereby empowering graduates to make important contributions to science-related fields and society-at-large. Louise and Brianna have developed and taught award-winning authentic scientific curricula focused on supporting students to take on the role of a scientist. It became apparent through their teaching that there was a paucity of fit-for-purpose resources to support students in their journey of scientific discovery, and development of scientific research and communication skills. Louise and Brianna enthusiastically embarked on a journey to fill this void, resulting in this etextbook *How to Do Science.*

## OTHER CONTRIBUTORS

This edition of *How to Do Science* was revised by biomedical and library staff at the University of Southern Queensland:

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We thank the many human physiology students whose enthusiasm and passionate engagement in development of scientific skills inspired us to create this resource. We express our gratitude to Dr John Waters, Mr Bill Perrotti and Dr Valerie O'Loughlin – past presidents of the Human Anatomy and Physiology Society – who first recommended we publish the How to do science guide with the intention for it to be used as a resource for science students worldwide. Their enthusiasm and encouragement set us on the path to publishing this e-textbook. We also thank Carrie DeHaan, Kirsten Duncan, Tim Meyen and the rest of the Biotext team for their outstanding editing and design work that elevated our work, and resulted in an e-textbook that exceeded our hopes and initial vision. This project would have been impossible without the support of a La Trobe University Digital Learning Strategy Innovation Grant, and the opportunities and support provided by La Trobe University Library staff Fiona Salisbury, Deputy Director Learning and Teaching, and Jennifer Peasley, Executive Director and University Librarian.

**Louise Lexis and Brianna Julien** (La Trobe University).

# *Introduction*

So, you've decided to become a scientist.

It is a wise choice, as the knowledge and skills gained by science, technology, engineering and mathematics (STEM) graduates are valuable in many careers, including in the government, business, law, education and health sectors (West, 2012).

## WHAT IS IN THIS GUIDE

*How to do science* has been written for students of the life sciences who are actively engaged in the scientific process. There is a lot of support available for students learning scientific facts, but we found that it was harder to find resources to support students to become scientists.

This guide introduces you to what it means to be a scientist. You will learn about the scientific method (**Chapter 1**) and how to carry out many tasks of a scientist, including:

- designing experiments to test a hypothesis (**Chapter 2**)
- performing simple statistics (**Chapter 3**)
- visualising data by creating graphs and tables (**Chapter 4**)
- accessing scientific literature, and using referencing software (**Chapter 5**)
- communicating findings from original investigations through research papers, posters and oral presentations (**Chapter 6**)
- writing literature reviews and summaries (**Chapter 7**)
- communicating science to the non-expert audience (**Chapter 8**).

Finally, you'll learn about your roles and responsibilities as a scientist, possible career paths, and how to use your skills as a science graduate to get the leg up in the job market (**Chapter 9**).

## A BETTER WAY TO LEARN SCIENCE

A global issue facing the science disciplines in higher education is perhaps summed up in the title of an article published in *The New York Times* in 2011, 'Why science majors change their minds (it's just so darn hard)' (Drew, 2011). Research from the 1900s confirmed that students learn more by grappling with open-ended problems, rather than listening to lectures. But, lectures are far cheaper to produce and deliver. With many academics focused on bringing in research grants, inquiry-oriented learning has, to date, failed to become 'mainstream' in undergraduate science education.

In an attempt to address this problem, many science education experts have implored educators to deliver curriculum that encourages students to engage in the practice of science. For example, leading biological and life-sciences experts put out a call to educators to action change in the way we deliver undergraduate biology education worldwide (American Association for the Advancement of Science, 2011). The plea urges educators

to engage students as active participants in the scientific process, so they can be better prepared for the biology-related challenges of the 21st century.

What the experts made clear in their plea for better scientists is that recent advances throughout the life sciences require new approaches, and these advances call out for new ways to prepare all undergraduates, regardless of their eventual career paths. This is consistent with the recommendations of Australia's former Chief Scientist, Professor Ian Chubb, and other leading scientists, such as Professor Suzanne Cory, who is one of Australia's most distinguished molecular biologists (Jones et al., 2014).

After heeding the call to action change, and developing and introducing curriculum designed to engage students in the scientific process, we soon realised that support materials for life sciences enquiry-based education were lacking. Therefore, this guide was born out of necessity – because, as the famous saying goes – 'necessity is the mother of invention'.

This guide is suitable for life sciences students at all levels of undergraduate study, and could also be beneficial to postgraduate students.

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CHAPTER 1

# *Science and the Scientific Method*

Science is with us everywhere. Advances in technology and science are rapidly transforming our world – from growing food, developing medicines, making exercise regimes, recycling and presenting the daily weather report, to reading a map and using our mobile phones and computers.

The modern world would not be modern at all without the understandings and technology enabled by science. In the future, being science literate will be a necessity, not an option. We cannot escape from the significance of science.

This chapter introduces the concept of science and its importance in our lives (**Sections 1.1** and **1.2**). Student scientists will learn about what science is and how it works, and how science graduates are able to change society for the better (**Section 1.2**). **Section 1.3** warns the student scientist about pseudoscience, and how it differs from 'real' science – what you are here to learn.

**A student scientist is someone who is being formally educated about science and how to practise science, as well as developing scientific skills and attributes such as teamwork, communication, and personal and professional responsibility.**

## 1.1 HOW MEDICAL SCIENCE HAS SHAPED OUR HISTORY

Medical science includes a diverse range of specialities including anatomy and physiology, biochemistry, pathology, haematology, microbiology, immunology, and pharmacology to name a few. Within these various fields of study, many advances have been made through scientific investigation to improve our understanding of human biology, the basis of disease, and the diagnosis and treatment of disease. While the number of advancements are too vast to cover in a single text, we can gain an appreciation of the impact of these scientific advancements by a look at examples within physiology, one of the medical science areas of study.

> **Physiology is a branch of biology that deals with the normal functions and activities of living organisms and their parts. Physiologists are interested in the mechanical, physical and biomechanical functions of humans or animals, and their organs and cells.**

Understanding and appreciating the history of physiology provides a context for learning current physiology. It also highlights how scientific understanding can change, and how current beliefs may one day be obsolete. The timeline below presents some of the notable discoveries in physiology that have informed our understanding of the human body and treatment for many diseases. These scientists have all been awarded Nobel prizes in Physiology or Medicine for their discoveries.

Box 1.1: Timeline of physiology discoveries

The website PhysiologyInfo.org, sponsored by the American Physiological Society, presents a timeline of physiology that highlights important discoveries between 1822 and 2013. General physiology milestones are presented in addition to milestones in endocrinology and metabolism.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=5#h5p-1

## 1.2 CURRENT ISSUES IN MEDICAL SCIENCE

Every day scientific advancements that significantly enhance our understanding of physiology and quality of life are revealed. The American Physiological Society has identified six 'hot topics' in the life sciences that are particularly important today:

- cancer biology
- cardiovascular biology
- exercise and metabolism
- inflammation and immunity
- the microbiome (previously known as the gut flora)
- stem cells and regeneration.

**Box 1.2** highlights some recent breakthroughs in four of these six key themes.

Box 1.2: Recent breakthroughs in physiology

Click on the drop-downs to read more.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=5#h5p-2

## 1.3 SCIENCE LITERACY

A science degree helps students develop science literacy, so that graduates can contribute to society positively. Experts including science academics, science students, employment groups and professional societies identified three elements of science literacy that a science student should understand by the time they graduate (**Figure 1.1**).

Graduates with scientific literacy are well prepared to participate in decision-making and debate socio-scientific issues that will improve society.

> The scientific method is the procedure of systematic observation, and forming, testing and modifying hypotheses.

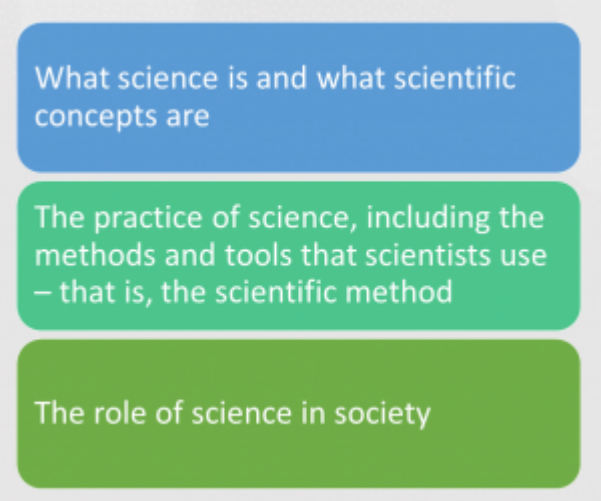


*Figure 1.1: Elements of scientific literacy. Source: Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

In high school and university, we learn science mostly from textbooks, which often presents science as absolute facts that we have always known. What the textbook doesn't make obvious is that these facts are only the best current information we have, and that these facts are the results of years of work by many scientists experimenting.

To fully understand science, we need to know how scientists conduct science and obtain facts.

Cutting-edge knowledge at the frontier of science is not as thoroughly tested as the well-tested and long-standing knowledge existing in contemporary textbooks. New data may not stand up to the test of time. New theories, ideas and possibilities can easily disappear as research progresses and data are generated. What might have been initially imagined by the physiologist as a 'break-through' discovery can easily end up as nothing more than a hypothesis without data to support it.

Student scientists should have the opportunity to appreciate the full scope of science during their undergraduate degrees, which includes the freedom to imagine new ideas, but with adequate educator support to actually take on the role of a scientist and test these ideas. This way, a student can learn about and understand science.

### Knowledge of science concepts, or 'what do we know?'

The first element of scientific literacy is the most obvious – knowledge *in* science or the collection of facts that science has produced. Student scientists spend a large part of their undergraduate degrees learning scientific facts in their discipline area – that is, they focus on 'what we know' and not on 'how we came to know it'. Scientific facts are claims about the world that can be directly established by a careful, unprejudiced use of the senses, or repeated and verifiable observations.

Scientific knowledge tells us about the nature of the world beyond what we see on the surface. It tells us about our cells and the organelles within, the transmission of energy from light hitting the retina in the eye to the electrical energy travelling down the optic nerve, and even about the conditions that existed in the world long before humans were around to observe it.

#### *Scientific theory*

The ultimate goal of science is to understand the natural world in terms of scientific theories – that is, concepts based on what we learn from experimentation. In science, our understanding is constantly increasing and, as a result, our theories develop and change.

In science, the word 'theory' is reserved for a conceptual scheme supported by a large number of observations; **Figure 1.2** shows five currently accepted scientific theories.

Scientific theories cannot be conclusively proved or disproved, and they change when evidence requires it. Once theories are proposed to explain the facts on a particular topic, they are rigorously and ruthlessly tested by observation and experiment. Theories that don't stand up to observational and experimental tests are eliminated and replaced by new potential explanations that must also be tested. Science progresses through the process of trial and error, by educated guesses and dismissals – only the most likely theories survive (see **Box 1.3**). Theories can never be described as true – rather, they are the best available explanations that are an improvement on anything we have had before.

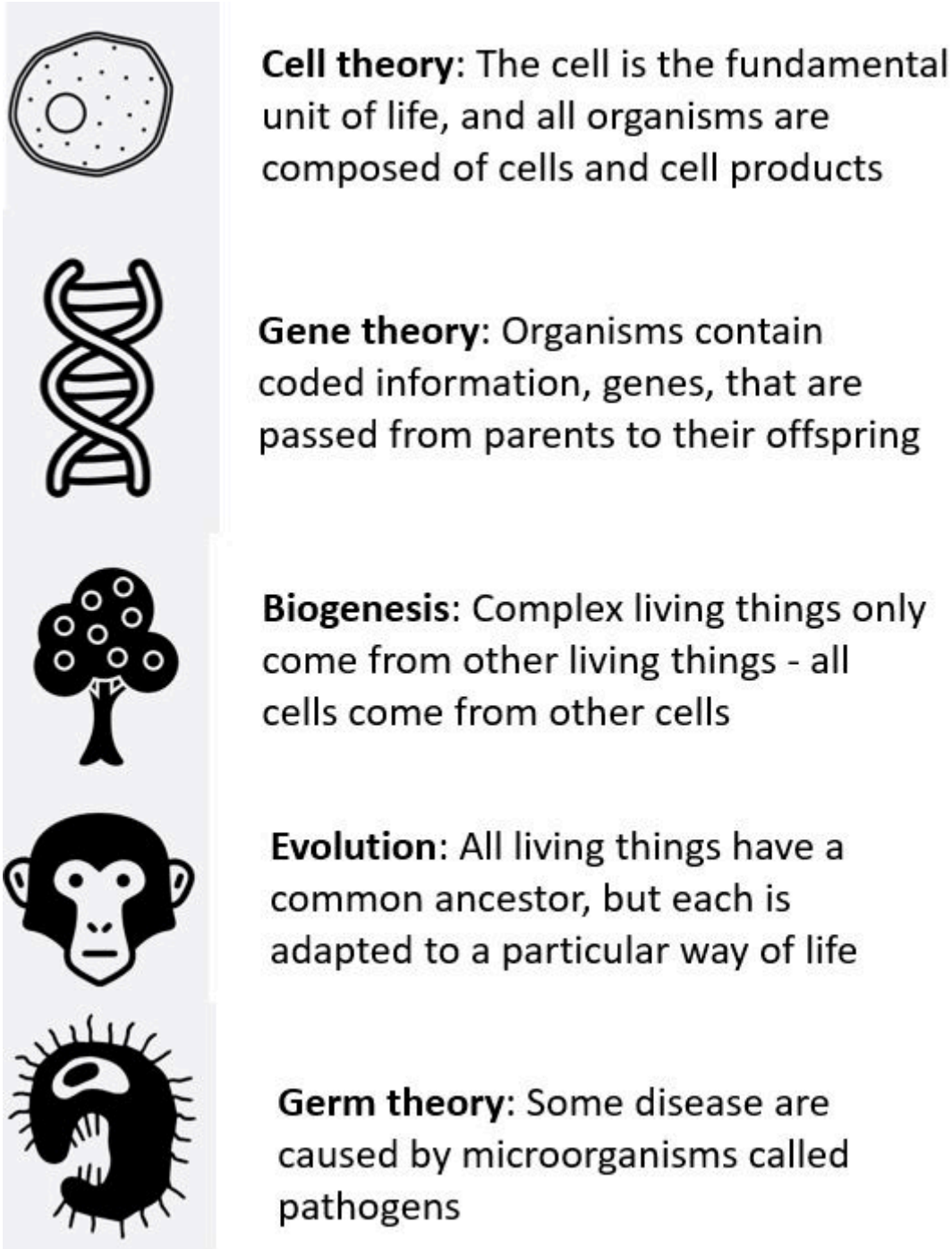


*Figure 1.2: Examples of scientific theories.* ***Source:*** *Icons from the Noun Project used under CC-BY licence. DNA icon by Josy Dom Alexis. Fruit tree icon by Ahmad Avatar. Monkey icon by Maxim Kulikov. Remaining icons in Public Domain.*

Box 1.3: Scientific hypothesis, testing and theory

Science starts with problems associated with explaining some behaviour of the world or universe in light of an existing theory. An example given by Chalmers (2013) is the observation that bats can fly well at night, even though they have small, weak eyes.

This observation is problematic in light of the theory that living creatures see with their eyes. A potential answer will be proposed to explain the observation – that is, a hypothesis. The hypothesis will then be tested and eliminated, or be successful. Once a hypothesis has managed to withstand a wide range of rigorous tests, it may become a theory and the scientist will move on to another problem and begin the process again.

It can take a lot of evidence and time to change established theories. There are many examples in science where theories were believed even when there was a great deal of opposing evidence – as explored in **Box 1.4.**

Box 1.4: The difficulties in changing scientific theory

Widely accepted during the 18th and 19th centuries, the miasma theory of disease transmission explained the origin and spread of some epidemic diseases like cholera. According to the theory, these diseases were caused by miasma (Greek for pollution) – an ill-defined, poisonous vapour secreted by rotting organic matter, or a noxious form of 'bad air' (**Figure 1.3**).

In 1546, Italian physician, poet, astronomer and geologist Girolamo Fracastoro first proposed a hypothesis that contradicted the miasma theory – that contagious diseases were caused and spread by transferrable seed-like bodies. Other scientists proposed similar hypotheses , but it wasn't until the work of Louis Pasteur and Robert Koch in the late 1860s that the germ theory became widely accepted. Joseph Lister, who came to be known as the 'father of modern surgery', applied the advances made by Pasteur to the hospital environment and introduced sterilisation of equipment, bedding, gowns and wounds, and washing hands to prevent infection.

*Figure 1.3: Robert Seymour. 1831. Cholera 'Tramples the victors & the vanquished both.' Public Domain.*

Lister faced opposition despite the positive results he was achieving. It didn't help that bacteria were too small to see – but eventually his aseptic techniques were adopted throughout Germany, the United States, France and, finally, Great Britain.

Sometimes scientists believe in a hypothesis so much that they may think they are observing things that are not there. The canals of Mars are a fascinating (although non-physiological) example of this.

In 1877, Italian astronomer Giovanni Schiaparelli reported the discovery of canals on Mars (Hetherington, 1976); many astronomers including Percival Lowell (1911) and Eugène Antioniadi (1930) also documented seeing the canals and drew detailed maps. Around 1895, these drawings led to Lowell concluding that the canals were an irrigation system developed by Martians. When more sophisticated telescopes and imaging technology were available, astronomers including Antioniadi proposed that these canals were an optical illusion caused by dust moving across the surface of Mars due to heavy winds (Gifford, 1964). This was supported by images obtained in the 1960s by unmanned NASA spacecraft.

The facts we learn about physiology as student scientists are the results of years of careful, slow work by teams of scientists. Their results – and therefore our knowledge – is constantly evolving. Textbook 'facts' may have been challenged, and may still be challenged and evolving.

This leads into the second element of scientific literacy: understanding how we came to know scientific facts and theories.

## Knowledge of the scientific method, or 'how did we come to know it?'

> Scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning (Newton, 1726/1999, pp 794-796)

The scientific method includes the elements shown in **Figure 1.4.**

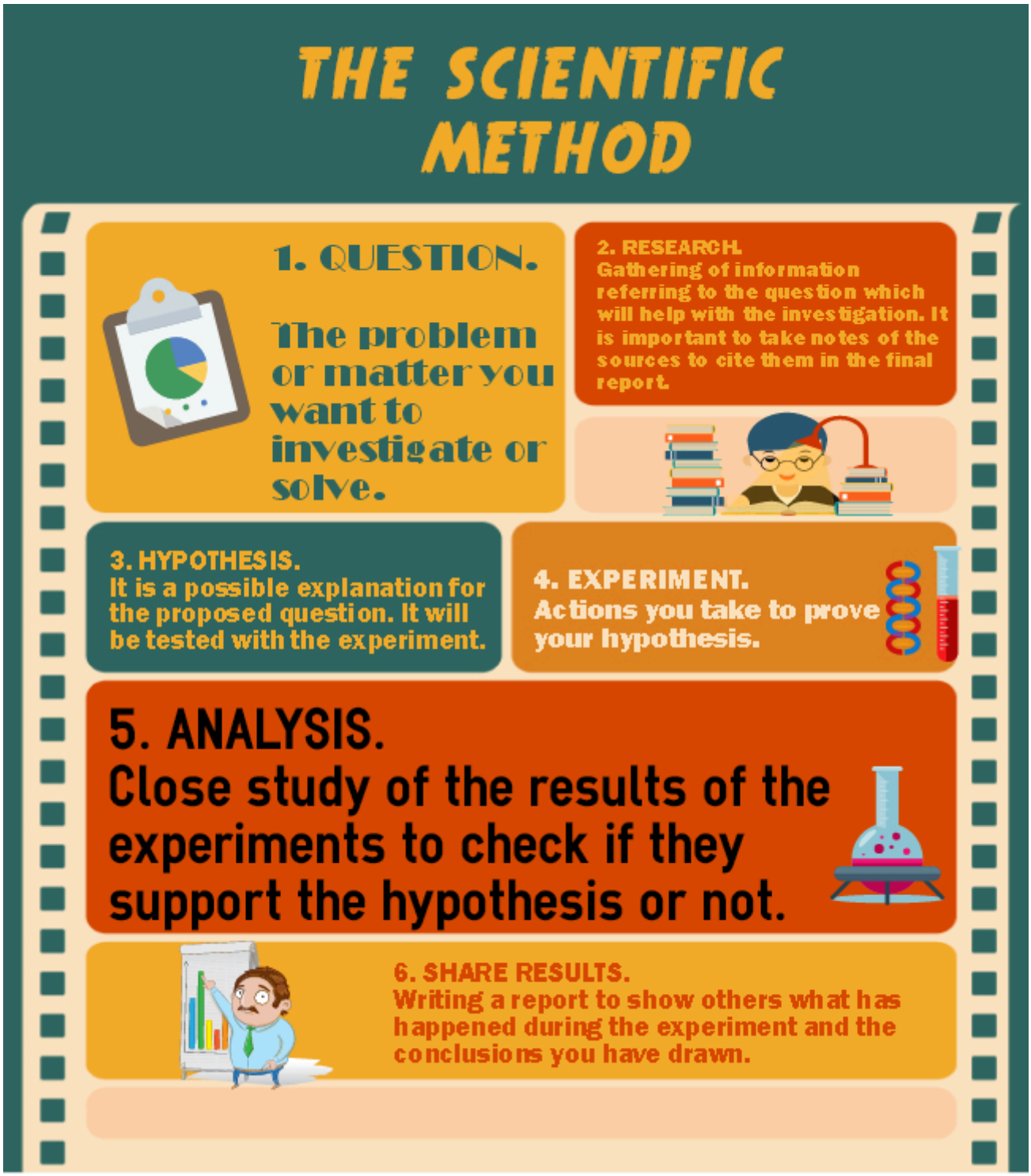


*Figure 1.4: Elements of the scientific method.* **Source:** *Image by Yolanda Varela used under a CC-BY-NC-SA 2.0 licence.*

In a speech to graduating students at the California Institute of Technology in 2016, Atul Gawande, a surgeon and public health researcher, said:

> Science is not a major or a career. It is a commitment to a systematic way of thinking, an allegiance to a way of building knowledge and explaining the universe through testing and factual observation (Gawande, 2016).

The process of making new discoveries in science is not as straightforward and neat as it may first appear. As a student scientist, you read textbooks, and conduct 'cookbook' practicals in which you follow a series of steps. In practice, creating new knowledge in science is characterised by difficulties, uncertainties and competing hypotheses

Science is a huge discipline, and the way science is done depends on the field of study. Exactly how a scientist conducts their craft depends on what knowledge and answers they are pursuing. For example, astronomers and geologists base their understanding on field observations, whereas physiologists and chemists base their understanding on experiments.

To a physiologist, the scientific method means implementing a series of experimental steps to create new knowledge and develop a more sophisticated understanding of a particular topic.

The scientific method follows seven general steps (see **Figure 1.5**):

1. make an observation
2. research what is already known about the topic (literature review)
3. form a testable hypothesis that may explain the observation
4. perform an experiment or series of experiments
5. analyse the results
6. accept or dismiss the hypothesis (conclusion)
7. share the results.

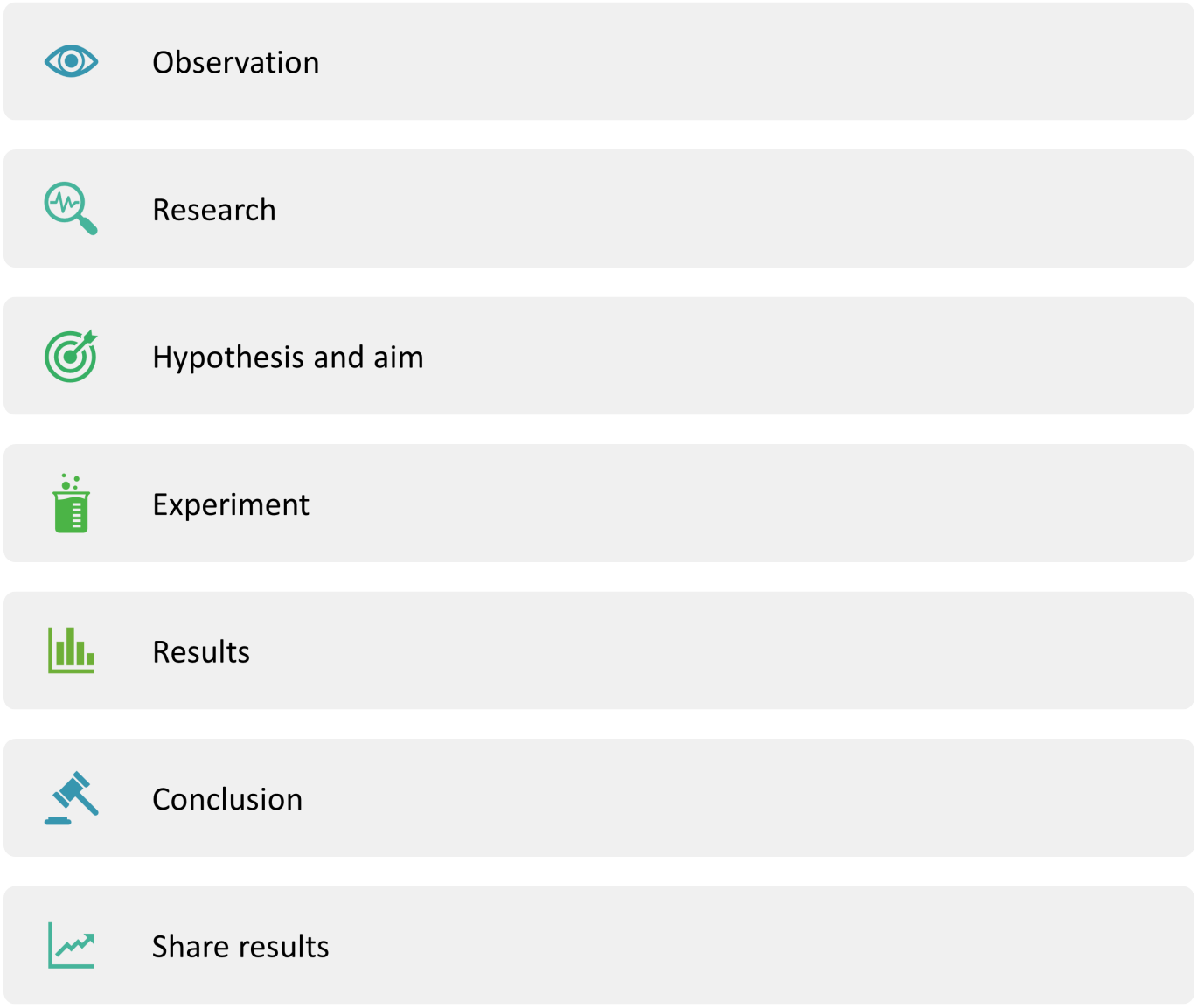


*Figure 1.5: The scientific method.* ***Source:*** *Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

Some philosophers and scientists prefer to see the scientific method as an ideal rather than a rule or a description of the practice of all scientists. Scientists are humans, and this means that we are not perfect and we are different in terms of our motivation, drive and ideas – all of which may result in science being practised differently.

Scientists may approach their quest for new discoveries differently, but they will always seek evidence that can be obtained in different ways. The scientific method combines rational thought and imagination to predict and explain phenomena, and the work of scientists is always open to scrutiny, criticism and debate.

**Figure 1.6** shows a cyclic model of the scientific method, indicating how it is an ongoing process.

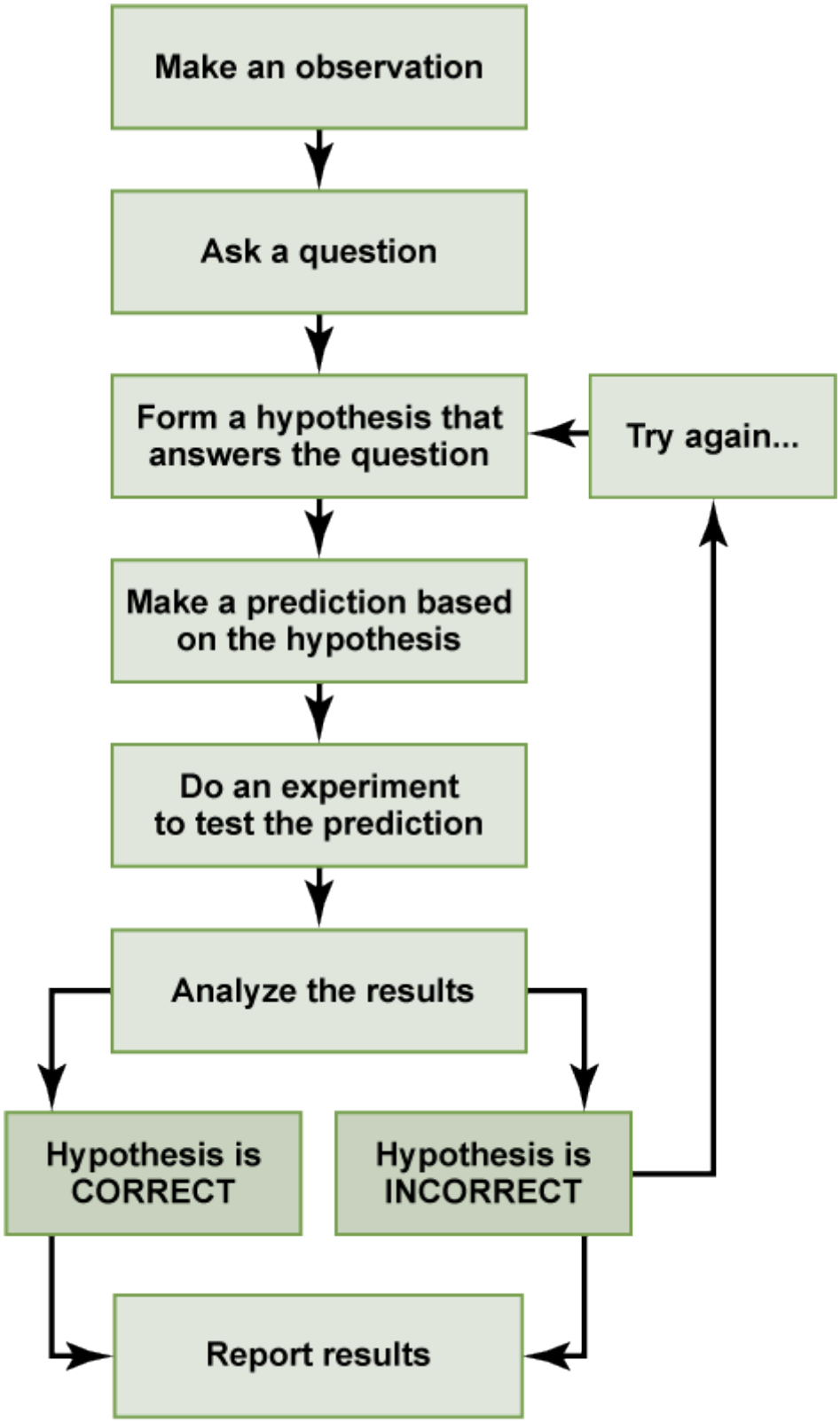


*Figure 1.6: The scientific method as an ongoing process. Source: Scientific Method by OpenStax, used under a CC BY 4.0 licence.*

Video 1.1: Video overview of the scientific method [7 mins, 32 sec]

TED-Ed presentation by Adam Savage on two spectacular examples of profound scientific discoveries that came from simple, creative methods that anyone could have followed.

**Note:** Closed captions are available by selecting the CC button below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=5#oembed-1

### *Observation and research*

Scientific research starts with a scientist making an initial observation that they cannot explain with an existing theory. It can also be a more open-ended questions, such as 'How can I treat this particular disease?' The scientist will study any previous data – that is, review the existing literature on the topic area, which are facts relevant to the problem at hand. This research may reveal that another scientist has already answered the question and, in this case, a new question will be asked. If the question hasn't been answered, the scientist will use the findings of their research to help them to design a good question that they can test.

### *Hypothesis and aim*

Research, and imaginative and creative thinking help the scientist to formulate a hypothesis that they can test to explain an observation or answer a question. A hypothesis is an assumption based on knowledge obtained during the observation stage – it is an 'educated guess'.

Data generated during an experiment either support or fail to support the hypotheses. Hypotheses may be specific (e.g. chronic ingestion of artificial sweeteners causes weight gain in humans) or broad (e.g. viruses cause disease in animals). Hypotheses are always subject to modification.

It is important to note that hypotheses, however, may be proven untrue. This occurs when the data do not support the hypothesis, in which case, the hypothesis must be rejected or refined.

A hypothesis is tightly linked to the aim of the study, which is the objective or goal of an experiment or series of experiments. The aim is written in a similar manner to the hypothesis. A hypothesis is a prediction about the outcome of an experiment; an aim is usually written in the form of an instruction:

**Hypothesis**: chronic ingestion of artificial sweetener causes weight gain in humans.

**Aim:** To determine if chronic ingestion of artificial sweetener causes weight gain in humans.

### *Experiment*

Physiologists conduct experiments to test whether the real world behaves as predicted by the hypothesis. The purpose of the experiments is to find out if the resulting observations of the real world agree or conflict with the prediction – if they agree, we can be more confident that the hypothesis is true, but if they disagree we become less confident.

Experiments are a valuable scientific tool, because when experimenting we are able to control and manipulate phenomena and events. However, this also means that we are creating an 'artificial environment' for our experiments. This may not end up reflecting what is happening in the real – messy – world.

Experiments will only help us to support or not support hypothesis if they are carried out properly. This means using care and the right equipment and settings, and the with goal of minimising error. If we conduct

careless experiments that introduce error into the results, the observations (or data) are useless when we try to evaluate our hypothesis.

Part of understanding how science works includes becoming aware of the methods and tools of science. Each scientific discipline has its own specialised techniques and tools that it uses to observe the natural world; student scientists will be exposed to some of these methods in practical classes during their studies. Experimental methods are not perfect, even when scientists try their best, and they can be updated or replaced over time. Advances in technology or scientific understanding may mean that previously accepted methods are rejected and replaced with new ones. This may also mean that experimental results obtained using old methods are also ignored, or viewed as less relevant, because our way of thinking about the topic has changed.

It is not always easy and straightforward to conduct well-designed experiments and to get reliable results. New experiments may take months or even years to perfect. Scientists need to work hard to collect high-quality results, including:

- developing their theoretical and practical knowledge of an area and a technique
- learning through trial and error
- mastering the available technology.

Researchers must provide details on how their experiments were conducted, because other researchers must be able to repeat the results. If results cannot be repeated, the hypothesis is no longer supported, and the conclusion may be incorrect. When the results of experiments are shared with the wider scientific community, the research will be judged on many things, including the methods employed.

Also, it is very rare for a researcher to generate their experimental methods from scratch; it is more common to use methods that have been shown by other researchers to be successful at measuring particular variables. This is another reason it is important to provide details of your methodology.

### *Results*

Scientists collect the data generated from their experiments and analyse them to determine whether the hypothesis was supported or not. In the analysis stage, the scientist combines the results from repeated experiments and carries out statistical analysis to test the hypothesis – for example, to determine whether differences exist between different experimental groups. Scientists will present their results as text, tables and graphs.

Results should be reproducible – that is, another scientist should be able to follow the same method and obtain the same results. If they are not able to do this, it may mean that the original results were an error. For this reason, scientists will usually conduct a single experiment multiple times.

Scientists rarely attempt to replicate the findings of other scientists, despite the importance of reproducibility. There are few incentives for scientists to dedicate time to replicating existing studies, and it can be difficult to replicate studies because the methods may be unclear, and poor or incorrect study designs may have been used in the original research (Belluz et al., 2016).

Recently, some scientists have found that when they do try to replicate studies, they have not been able to obtain the same results. This has led to a 'crisis of reproducibility'. Scientists who have investigated reproducibility have found that few findings published in top psychology journals as well as highly cited papers on psychiatric treatment (Tajika et al., 2015) could be replicated (Open Science Collaboration, 2015). This issue is gaining more attention and must be addressed by scientists from all disciplines.

### *Conclusion*

Conclusions are made about the results of the experiment in light of the hypothesis. Simply, the results do

or do not support the hypothesis. The conclusions below are the two possibilities arising from the example hypothesis and aim shown previously:

**Conclusion**: Chronic ingestion of artificial sweetener caused weight gain in humans.

**Conclusion**: Chronic ingestion of artificial sweetener did not cause weight gain in humans.

The study hypothesis, aim and conclusion are therefore highly connected.

Scientific conclusions are subject to change when new findings dictate that they need to be changed. Quite often in science, new studies, which might use new techniques and equipment, tell us when conclusions need to be modified or changed entirely.

### *Share results*

Results of experiments should be shared with the wider scientific community, so they can contribute to the pool of knowledge on a topic and lead to better understanding for everyone.

Scientists can communicate with their peers in different ways:

- make an oral presentation at a conference
- present a poster at a conference
- publish a journal article in a peer-reviewed academic journal (see **Box 1.5**).

Publication of results makes information widely available and the results will be used by others if they are seen as interesting – results not deemed interesting will fade from sight; sadly, this is the fate of most published articles.

**Box 1.5: Peer-reviewed articles and academic journals**

Results do not become a part of the pool of shared knowledge until they are published, but not all results achieve this outcome. Scientists must present their findings in the accepted format – that is, a journal article, and convince journal editors and referees that their work is interesting, sound and useful.

Once a journal editor accepts an article, it is subjected to peer review. This is where others scientists with expertise in the relevant field, usually anonymously, read through and check that the work is of sufficient quality and worthy of publication. The publication and peer-review process is at the mercy of people and therefore not perfect – error, bias and dishonesty is inherent. As a result, some research that should be published isn't – and some research that shouldn't be published is.

This is a stressful process because research scientists in universities and industry aim to publish their work in academic and professional journals. Their publication record is tremendously important to scientists because it is often used to judge the quality of their work. Ultimately, a researcher's publication record determines whether they get or keep jobs, or gain funding to continue their work.

Interesting and important results will be cited by other scientists in the field who will test the results, and often modify and extend on the research. They may also report back if they find something wrong or inadequate in the research. Results that withstand scrutiny by peers and continue to be seen as interesting, useful and correct (or not obviously wrong) will make their way into secondary literature, that is review articles, monographs and graduate-level textbooks. If more time passes and the results are still interesting and correct, they will find their way into undergraduate textbooks, which have the widest reach and influence.

An example of the scientific method is shown in **Box 1.6**.

The language used in presentations and journal articles is highly technical and will contain a lot of scientific jargon. A non-expert audience will struggle to understand the meaning of such publications. To communicate their findings to lay – or non-expert – audiences, scientists may talk about their work during, for example, a radio or television interview.

**Chapter 6** and **Chapter 7** discusses the ins and outs of writing technical publications, and **Chapter 8** talks more about communicating science to the non-expert audience.

Box 1.6: The scientific method in action

**Observation**: A physiologist determines that available evidence indicates that say drug X – which is not yet approved by Australia's Therapeutic Goods Administration – increases the metabolic rate, and may therefore be a promising weight loss drug.

**Hypothesis**: The physiologist hypothesises that 'drug X will cause weight loss in adult rats'.

**Aim**: The physiologist plans a study, with the aim to 'determine if drug X will cause weight loss in adult rats'.

**Experiment**: The physiologist randomly assigns 20 adult rats to a control and treatment group – 10 per group. The control group is administered a daily dose of the placebo and the treatment group is administered a daily dose of the drug for 4 months. The control group receives a placebo instead of a drug, and all other conditions are identical to the treatment group with the exception of the drug. They receive the same kind of food and water. Body weight is recorded daily.

**Results:** At the end of the 4-month treatment period, the physiologist performs a statistical analysis on the body weight data. The data reveal that there is a statistical difference between treatment groups, with the treatment rats weighing less than the control rats.

**Conclusion:** Drug X caused weight loss in adult rats.

**Share results:** The physiologist will share their work with peers through a poster or oral presentation at a conference, and/or a journal article.


*Figure 1.7: The Scientific method in action. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Knowledge and appreciation of science in society, or 'how can we contribute'?

Understanding how science influences society – and vice versa – is an important aspect of scientific literacy. Science graduates who are able to combine their scientific knowledge and how it works with an understanding of the role of science in society will be valuable citizens who can contribute effectively to debates and decision making about science-related public issues.

One of the roles of a science graduate is to uphold the reputation of science in society by explaining what it is and why it is important. Many members of the public misunderstand what science is, what it means if something is scientific, and how science and technology are related. Some scientists may also share these misunderstandings (Bauer, 1992).

Video 1.2: Science and Society [4 mins, 37 secs]

Watch this video interview with Steven Pinker, renowned experimental psychologist and Professor in the Department of Psychology at Harvard University, on the place of science in society.

**Note:** Closed captions are available by selecting the CC button below,

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=5#oembed-2

Many people already do respect science, and this has been exploited in some advertisements that tell us that a product has been 'scientifically proven' to be better, stronger, faster, more efficient or even sexier than its rivals. This is meant to make the product more attractive to consumers because it implies that the claims are well founded and perhaps beyond dispute (Chalmers, 2013).

On the other hand, some people do mistrust science, as evidenced by some views about climate change and childhood vaccinations. Although most scientists agree that climate change is occurring, some of the public still view it as an issue that is up for debate. And despite the evidence supporting the positive impact of immunisation on human health, some parents are reluctant to vaccinate their children.

Scientists are responsible for discoveries that have resulted in nuclear weapons and pollution, and – as a result – are distrusted by some members of the public. A study published in 2012 reviewed data collected from American citizens on their social attitudes from 1974 to 2010 (Gauchat, 2012). The author found that trust in science has not declined during this time period, except among people who described themselves as politically conservative and those who frequently attended church. Also, levels of trust in science varied a lot according to social class, ethnicity, gender, and region. This is not surprising, given the way science and scientists have treated some populations – for example, African–American men in the Tuskegee study (see **Case Study 1.1**).

### Case Study 1.1: Tuskegee study and distrust of doctors among African–Americans

Marcella Alsan and Marianne Wanamaker published a working paper in the National Bureau of Economic Research in 2016 (Alsan & Wanamaker, 2016); the abstract summarises their study.

Alsan and Wanamaker's research showed that the unethical study may have led to a distrust in doctors, which contributed to (~35%) African–American men avoiding the health care system and therefore dying earlier. This effect was stronger the closer the men lived to Macon County, Alabama, where the Tuskegee study took place.

Although science influences how society functions, it is also true that society influences which topics are chosen for research and government funding. In 2015, the Australian Government developed a set of Science and Research Priorities. This project was led by the former Chief Scientist, Professor Ian Chubb, and included consultation with researchers, industry leaders and government representatives, who together represent all citizens. The areas that have been chosen as priorities are those deemed to be of critical importance to Australia and will be given public funding. They are:

- Food
- Soil and water
- Transport
- Cybersecurity

- Energy
- Resources
- Advanced manufacturing
- Environmental change
- Health

## 1.4 PSEUDOSCIENCE

> "Pseudoscience is the form of science without the substance." (Gawande, 2016)

Pseudoscience describes an idea, field, practice, body of knowledge or belief that is presented as being scientific, but does not follow or obey the scientific method, and is not consistent with the standards of scientific research.

In 2006, the National Science Foundation (in the United States) analysed survey data from the previous 20 years and found that many Americans have many pseudoscientific beliefs, including astrology, lucky numbers, the existence of unidentified flying objects (UFOs), extrasensory perception (ESP) and magnetic therapy (National Center for Science and Engineering Statistics, 2006). They found that belief in pseudoscience increased during the 1990s and early 2000s, but declined between 2001 and 2005. In 2012 (National Center for Science and Engineering Statistics, 2014):

- 55% of Americans said astrology is 'not at all scientific'
- 32% said they thought astrology was 'sort of scientific'
- 10% said it was 'very scientific'
- about 4% said they 'did not know'.

These numbers have not changed dramatically since surveys began, indicating that there is much for science communicators to achieve. Other examples of pseudoscience include acupuncture, alchemy, astrology, homeopathy, intelligent design and physiognomy.

Box 1.7: Characteristics of pseudoscience

- **The use of vague, exaggerated, or untestable claims:** Many claims made by pseudoscience cannot be tested with evidence. As a result, they cannot be falsified, even if they are not true.
- **An over-reliance on confirmation rather than refutation:** Any incident that appears to justify a pseudoscience claim is treated as proof of the claim. Claims are assumed true until proven otherwise, and the burden of disproof is placed on skeptics of the claim.
- **A lack of openness to testing by other experts:** Practitioners of pseudoscience avoid subjecting their ideas to peer review. They may refuse to share their data and justify the need for secrecy with claims of proprietary or privacy.
- **An absence of progress in advancing knowledge:** In pseudoscience, ideas are not subjected to repeated testing followed by rejection or refinement, as hypotheses are in true science. Ideas in pseudoscience may remain unchanged for hundreds — or even thousands — of years. In fact, the older an idea is, the more it tends to be trusted in pseudoscience.
- **Personalization of issues:** Proponents of pseudoscience adopt beliefs that have little or no rational basis, so they may try to confirm their beliefs by treating critics as enemies. Instead of arguing to support their own beliefs, they attack the motives and character of their critics.

- **The use of misleading language:** Followers of pseudoscience may use scientific-sounding terms to make their ideas sound more convincing. For example, they may use the formal name dihydrogen monoxide to refer to plain old water (Miller, 2020).

## Defenders of science have identified hallmark moves of the pseudoscientist, as shown in **Box 1.7.**

Scientifically literate graduates are able to improve society by combatting pseudoscience, as discussed in the section 'Knowledge and appreciation of science in society'.

Resource

Australian researchers John Cook and Professor Stephan Lewandowsky wrote The Debunking Handbook, a guide to defending science as a more valid approach to explaining the world.

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=5#h5p-3



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CHAPTER 2

# *Design for Discovery*

New and exciting scientific discoveries that have a positive impact on humanity are not usually stumbled upon by chance. Scientists systematically go about their work to create new knowledge in many important areas such as the treatment and prevention of disease.

We gain improved understandings of our natural world when scientists dedicate themselves to the pursuit of discovery by carefully preparing for, planning and conducting experiments. A scientist's carefully controlled experiments produce data, and the data that build from many different – yet similar – experiments on a given topic provide evidence to help us understand more about a particular field or topic.

Effective experimental design is not haphazard; it is in itself a science, where a set of rules are followed to produce valid and reliable data.

In **Chapter 1**, we introduced the importance of scientific literacy, which includes the recommendation that student scientists understand science, including how we come by our scientific knowledge. We introduced the scientific method, of which a big component is experimentation. During your undergraduate degree, you will likely be given a chance to practise the scientific method and to design your own study.

This chapter will explain the principles of experimental design and lead you through some examples of experimental design in human physiology.

## 2.1 RESEARCHING HUMAN PHYSIOLOGY

> "Human research is research conducted with or about people, or their data or tissue." –(National Health and Medical Research Council & Australian Research Council, 2007 p. 3).

Although there is no one perfect definition of research, it is generally agreed that research includes investigation carried out with the purpose of gaining knowledge and understanding, or for training researchers. The Australian Research Council states:

> "Research is defined as the creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies, inventions and understandings. This could include synthesis and analysis of previous research to the extent that it is new and creative..." (Australian Research Council, 2022, para. 1).
>
> "In research in human physiology, investigators may use human participants or animal subjects. Animals are commonly used to inform our understanding of how humans work. In contrast, animal physiologists study animals to inform their understanding of how animals function." (Department of Education Skills and Employment, 2022).

In this chapter, we will provide some practical tips on writing hypotheses, aims and conclusions, and then focus on the 'experiment' step of the scientific method (**Figure 2.1**).

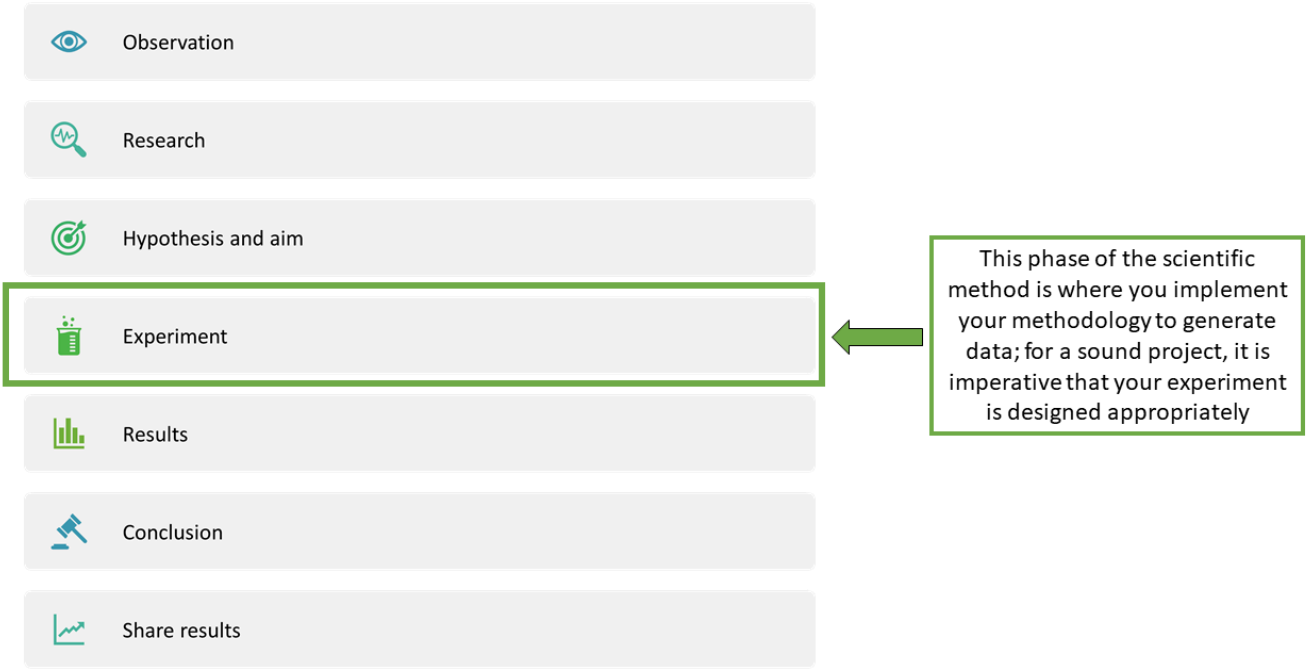


*Figure 2.1: The scientific method.* ***Source:*** *Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

## Where to start?

Before designing an experiment, you will have read some research on the existing scientific literature on a topic and made an observation you cannot yet explain. This process will lead you to write the hypothesis for the study. More scientifically put, the hypothesis is a prediction of the effect of the independent variable on the dependent variable in a scientific research study.

A hypothesis is an assumption or prediction based on sound evidence – that is, an 'educated guess'.

Scientists may differ on how they write their hypotheses; one simple model is presented here. Firstly, identify your **independent variable** and **dependent variable**; these are essential to the aim, hypothesis and conclusion of a study.

### *Independent variable*

- The variable that the investigator intentionally changes in an experiment to observe its effect on other variables
- **Example:** in an experiment where a scientist studies the effect of artificial sweetener on body weight, artificial sweetener is the independent variable

### *Dependent variable*

- The variable that changes in an experiment as a result of the independent variable
- Example: in an experiment where a scientist studies the effect of artificial sweetener on body weight, body weight is the dependent variable

Now that you have conducted research on the topic and decided on what you predict will happen under your

experimental conditions, and you have established your independent and dependent variables, you can use the following schema to write your hypothesis.

## Hypothesis

Simply replace the text in the boxes below with information specific to your experiment.

| | | | | | |
|---|---|---|---|---|---|
| Independent variable | will cause | dependent variable | to | predicted direction of change | experimental conditions |

For example:

| | | | | | |
|---|---|---|---|---|---|
| Artificial sweetener | will cause | body weight | to | increase | in healthy elderly humans |

Or:

| | | | | | |
|---|---|---|---|---|---|
| An acute dose of 100 mg of drug X | will cause | oxygen consumption | to | decrease | in healthy young adults |

Try to avoid hypothesising that your independent variable will have no effect on your dependent variable.

Here is a hypothesis written by a student with a suggestion for how it could be improved. The original hypothesis is missing some information that will make it clear and specific to the experiment that the student is planning to conduct.

**Original hypothesis that needs some work:**

| | | |
|---|---|---|
| Listening to fast music | will increase | activity in the cardiovascular system (CVS) |

**Revised hypothesis that is more precise and indicates what is being compared:**

| | | | | | |
|---|---|---|---|---|---|
| Music with a high tempo (150 beats per minute [bpm]) | will cause | heart rate and mean arterial pressure | to | increase | more than music with a low tempo (75 bpm) |

Now that you have your hypothesis, it is simple to slightly modify this statement to write your aim.

## Aim

The aim can be written using the same words as the hypothesis, with the addition of 'to determine the effect of' or 'to determine if' at the beginning of the sentence.

The aim of a scientific research study is to determine the effect of the independent variable(s) on the dependent variable(s).

Simply replace the boxes below with information specific to your experiment.

| | | | | | | |
|---|---|---|---|---|---|---|
| To determine if | independent variable | will cause | dependent variable | to | predicted direction of change | experimental conditions |

For example,

(this matches the hypothesis presented in the previous section):

| | | | | | | |
|---|---|---|---|---|---|---|
| To determine if | artificial sweetener | will cause | body weight | to | increase | in healthy elderly humans |

Or, (this matches the hypothesis presented in the previous section):

| | | | | | | |
|---|---|---|---|---|---|---|
| To determine if | an acute dose of 100 mg of drug X | will cause | oxygen consumption | to | decrease | in healthy young adults |

Here is an aim written by a student with a suggestion for how it could be improved. The original aim is missing some information that will make it clear and specific to the experiment that the student is planning to conduct.

**Original aim that needs some work:** Introduce participants to music with a range of BPMs in order to establish what effect if any the speed of music had on their CVS.

**Revised aim that is more precise and indicates what is being compared:**

| | | | | | | |
|---|---|---|---|---|---|---|
| To determine if | music with a high tempo (150 bpm) | will cause | heart rate and mean arterial pressure | to | increase | more than music with a low tempo (75 bpm) |

We're jumping ahead a bit, but it is a good place to discuss writing your conclusion. Your conclusion should be very tightly linked to your hypothesis and aim. In fact, you can base the wording of your conclusion on the wording of your hypothesis (and aim since it is written similarly to the hypothesis).

## Conclusion

The conclusion can be written using the same words as the hypothesis. Just change the wording slightly to indicate how the results compared with your prediction.

> A conclusion is the answer to your research question – a summary of how the results of a scientific study support or fail to support the hypothesis.

Simply replace the boxes below with information specific to your experiment.

| | | | | | |
|---|---|---|---|---|---|
| Independent variable | caused / or did not cause | dependent variable | to | observed direction of change | experimental conditions |

For example:

| | | | | | |
|---|---|---|---|---|---|
| Artificial sweetener | caused | body weight | to | increase | in healthy elderly individuals |

Or:

| | | | | | |
|---|---|---|---|---|---|
| An acute dose of 100 mg of drug X | did not cause | oxygen consumption | to | decrease | in healthy young adults |

Here are some conclusions written by students with suggestions for how they could be improved. The original conclusions are long-winded and wordy, and do not clearly link back to the hypothesis and aim.

Remember, if you collected usable data in your experiment, you can always state a conclusion! If you did not find a significant difference between groups or conditions, this is still a valid conclusion.

**Original conclusion that needs some work:** Despite the results indicating a slight increase in the cardiovascular system, statistical tests indicate that there was no statistically significant difference between the control and the music group. Therefore, due to the inconclusive results we cannot make any conclusions and further studies need to be completed.

**Revised conclusion that is more concise and reflective of what the student investigated:**

| | | | | | |
|---|---|---|---|---|---|
| Music with a high tempo (150 bpm) | did not cause | heart rate and mean arterial pressure | to | increase | more than music with a low tempo (75 bpm) |

**Original conclusion that needs some work:** Despite the results indicating a slight increase in time-to-exhaustion, statistical tests indicate that there was no statistically significant difference between the control and the caffeine group. Therefore, according to statistical tests, caffeine does not provide any additional benefits in improving time-to-exhaustion in cold conditions.

**Revised conclusion that is more concise and reflective of what the student investigated:**

| | | | | | |
|---|---|---|---|---|---|
| Caffeine | did not cause | running time to exhaustion | to | increase | in cold conditions |

**Original conclusion that needs some work:** An increased dosage of caffeine caused an increase in cognitive performance, however due to lack of statistical significant results, further research is warranted.

**Revised conclusion that is more concise and reflective of what the student investigated:**

| | | | | | |
|---|---|---|---|---|---|
| An acute dose of 150 mg of caffeine | did not cause | cognitive performance | to | improve | more than an acute dose of 50 mg of caffeine |

**Original conclusion that needs some work:** There were no statistically significant results, although a trend was observed with caffeine having a positive effect on cognitive performance.

**Revised conclusion that is more concise although some more information could have been included to better reflect the experimental conditions:**

| | | | | |
|---|---|---|---|---|
| Caffeine | did not cause | cognitive performance | to | improve |

Now let's design your experiment ...

## 2.2 DESIGNING AN EXPERIMENT TO TEST YOUR HYPOTHESIS

Now that you have your independent and dependent variables, an idea of your experimental conditions, and a hypothesis and aim, it's time to design your experiment.

### Control group experimental design

> In a control group experimental design, the participants are divided into two groups, one of which is designated the control and the other the experimental group.

Before you begin your physiology experiment, you will need to create groups. If the purpose of your study is to investigate the differences or the influence of an independent variable on distinct populations – for example, males and females – this task will be simple. You would simply place the males into one group and the females into the other group.

If your study is not investigating distinct populations, and the purpose of your study is to investigate the effect of an intervention that may have permanent or long-lasting effects, or the experiments will be terminal for animal subjects (e.g. mice or rat study where animals are sacrificed to harvest organs and tissues for analysis) you will have to be a bit more thoughtful. In this situation, you will create two groups – a **control** and **treatment**.

A key feature of this type of experimental design is that the groups contain different individual animal subjects or human participants.

#### *Control group*

This group of animal subjects or human participants are treated identically to the treatment group, except they do not receive or experience the independent variable of interest. This typically involves the use of a placebo (e.g. sugar pill) or a sham of the independent variable where possible (e.g. sham exercise)

#### *Treatment group*

This group of animal subjects or human participants are exposed to the independent variable of interest – for example, an acute dose of caffeine or a 5-kilometre run.

A simple 'before-and-after' comparison on the same set of individuals is not valid, because it does not control for extraneous time-dependent variables (e.g., developmental age and learning).

In a control group experimental design, you would typically only have one control group. But, you could have one or more treatment groups, depending on the specifics of your study.

## *Creating control and treatment groups*

### Random assignment

If you have large sample sizes, or if the group of animal subjects or human participants are very similar, you can randomly assign the animals or humans to the control and treatment groups.

For example, when inbred strains of rat of a particular sex and age are being studied, the animals are so similar – genetically and physiologically – that random assignment to treatment groups is highly unlikely to produce groups with systematic differences. Systematic differences can introduce extraneous variables that interfere with the results of your experiment (see the next section).

### Extraneous variables

An extraneous variable is an unwanted variable that is not the independent variable of interest, but influences the outcome of – and therefore adds error to – an experiment (Karanicolas et al., 2010). A major goal in research design is to decrease or control the influence of extraneous variables as much as possible. If you randomly allocate animal subjects or human participants that are very different to your control and treatment groups, you may find that these differences may influence the outcome of your experiment (see **Box 2.1**).

**Box 2.1: Extraneous variables in control and treatment groups**

You conduct an experiment on the effect of hormone Z on mice, and you randomly allocate your mice to control and treatment groups.

The control group is administered a placebo and the treatment group is administered hormone Z. The metabolic rates of all the animals are then measured, and groups compared, to determine whether the hormone has any effect on metabolic rate.

Imagine that random assignment had, by chance, resulted in two groups that differed substantially in average body mass or sex – although keep in mind that is more likely to occur in wild animals and not with specifically bred laboratory mice). This experiment would be unable to separate the effects of mass, sex and hormone treatment, all of which are known to affect metabolic rate.

In other words, in this example:

- mass and sex are the **extraneous variables**
- hormone treatment is the **independent variable**
- metabolic rate is the **dependent variable**

Introduction of such extraneous variables can be controlled by creating balanced groups – that is, experimental groups with no obvious differences.

### Balanced groups

If you don't have large sample sizes or your animal subjects or human participants are quite different, you should create balanced groups. Creating balanced groups will minimise or eliminate the effect of variables other than the ones you are investigating – that is, your independent variables.

To create balanced groups, baseline measurements are taken and are then used to create groups with no obvious differences. This may be simple, such as equally assigning male and female subjects or participants to each group (**Figure 2.2**). You may use

**Balanced groups are experimental groups with no obvious differences.**

measurements such as the mean body mass index, grade point average, short-term memory span or minutes of weekly exercise to balance groups (**Figure 2.3**).

The variables that you use to balance groups should be the same as, or closely related to those, that you will measure in the experiments. If there are large amounts of variables to measure, the scientist must determine what are the most significant variables that are needed to be controlled for.

After balanced groups are created, the independent variable is then introduced.

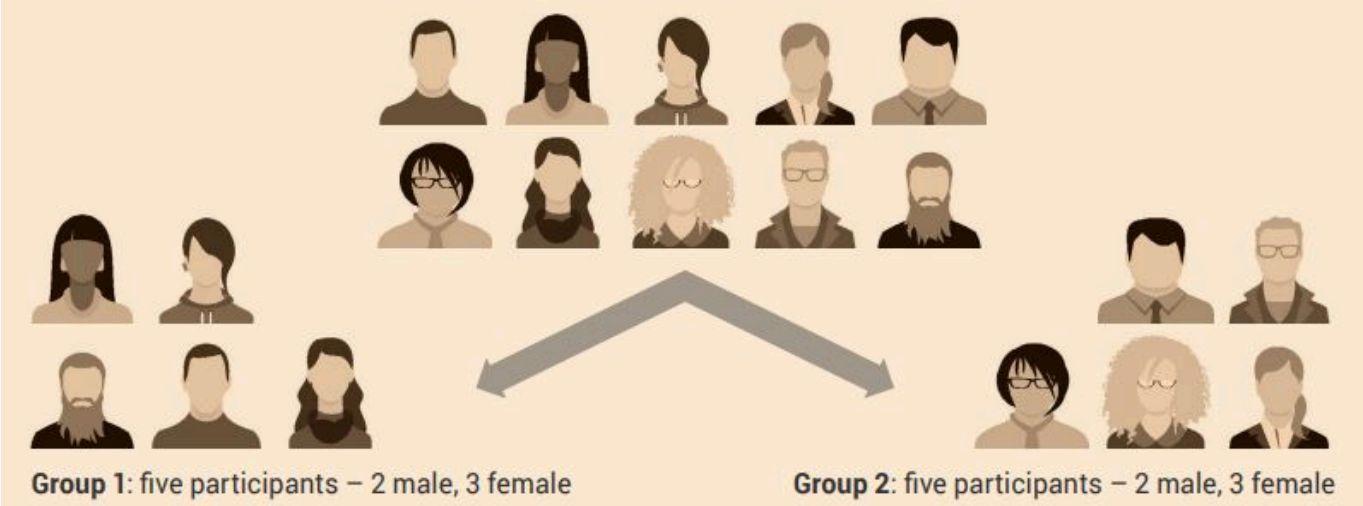


*Figure 2.2: Creating gender-balanced groups in a human study. Observe the gender of your participants and create groups with similar gender profiles if you believe that gender may influence the results. Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

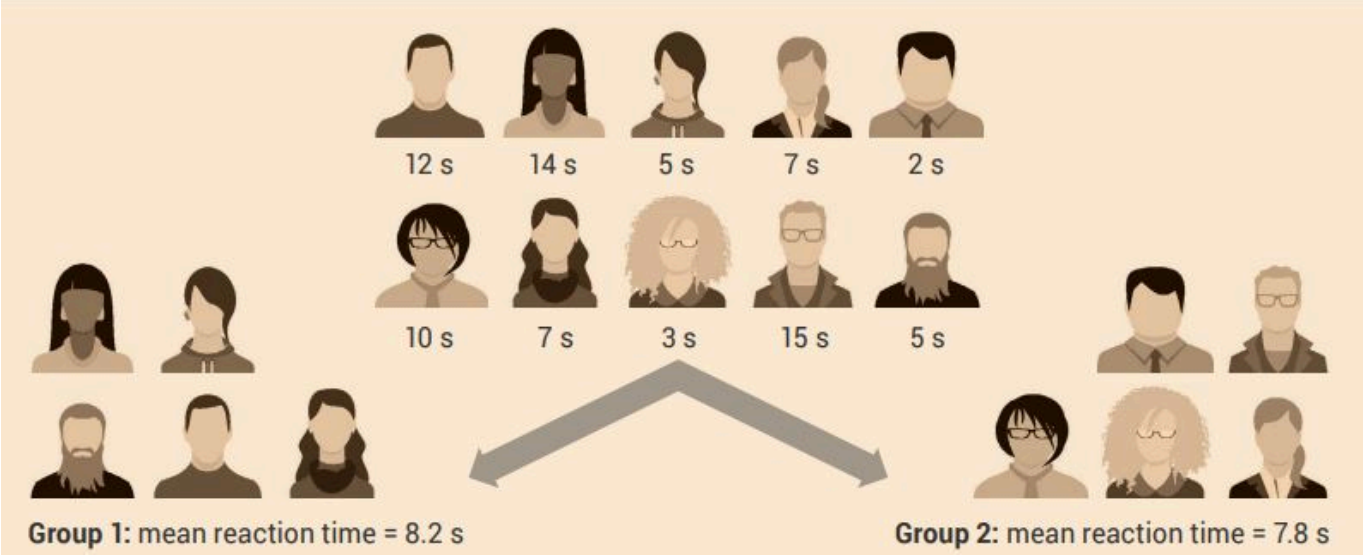


*Figure 2.3: Creating performance-balanced groups. For a study involving reaction time, record each participant's performance on a reaction time task and create groups that have similar average performance levels. Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Treatment order control / cross-over experimental design

> In a treatment order / cross-over experimental design, each participant is measured under the control and experimental treatment conditions, with one-half of the participants experiencing the conditions in reverse order.

You should use a treatment order control experiment design, also known as the cross-over experiment design for some types of experiments. For example, if you are investigating the effects of a treatment that only causes

short-term effects, and you are not studying the difference between distinct populations or using animal subjects where the experiment will be terminal for them.

In this experimental design you will decide on your conditions – for example, the effects of an acute bout of aerobic exercise on short-term memory. Instead of having two separate groups, one as a control (no exercise) and the other as a treatment group (exercise) as you would for the control group experimental design, each participant is measured under the control and treatment conditions, with one-half of the participants experiencing the conditions in the reverse order.

This type of design can also have more than one treatment condition. In this case, animal subjects or human participants will experience all conditions, but in a different order.

The analysis for a cross-over design considers only the differences between the two (or more) measurements (dependent variables) from each individual. This makes it a powerful design, because it eliminates the 'noise' resulting from differences between individuals. Put more simply, each animal subject or human participant acts as their own control (**Figure 2.4**).

> Experimental noise is the ...inherent variation existing between different subjects for a variable measured under control or treatment conditions.

It is important to note that physiological experiments that use animal subjects generally use the control group experimental design, and not the cross-over design. In animal studies, it is very common that the experiments are terminal.


*Figure 2.4: A cross-over experimental design with two conditions. All participants will experience both conditions (no exercise and exercise) before short-term memory testing with one-half of the participants experiencing the conditions in the reverse order. Numbers of human participants for illustration purposes only.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Placebos

A placebo is used in research studies that investigate the effects of medicines. The treatment group receives the medicine, and the control group receives a placebo – a dummy medicine that has no therapeutic effect. An example of a dummy medicine is a sugar pill that looks identical to the real medicine. Comparing the results from both groups should indicate the effectiveness and side-effects of the drug.

Placebos can be used in both control group experimental designs and cross-over designs. However, keep in mind that the cross-over experimental design would not be appropriate if:

- the drug was to be taken over a long period of time – say, years
- it could cure a disease or condition
- it had long-lasting effects.

Interestingly, in studies that used placebos, human participants don't know if they are receiving the dummy medication or the real thing, and sometimes not even the researchers know. We will expand on this concept of blinding a bit later.

> Logic should tell you that the placebo will have no effect. However, a strange phenomenon called the 'placebo effect' can occur, which is when people get better when they are taking the placebo. There are various hypotheses that attempt to explain this phenomenon, but the underlying mechanisms remain mysterious.

Another interesting piece of information that you may initially find odd is that placebos are also administered in animal studies.

Why would scientists do this? What's the point if the animals are not going to be psychologically concerned with the treatment – that is, why bother if there is no placebo effect?

Well, imagine a control group experimental design study where treatment rats are injected with a drug every day for a month. Remember that the only difference between control and treatment groups should be the independent variable – in this case, the drug.

Keep in mind that, in addition to the independent variable (the drug), the treatment animals will also receive an injection every day.

Can you determine what the placebo would be for this experiment?

If you said the control group would also receive a daily injection, but with just the drug vehicle (the substance that the drug is dissolved or suspended in, without the drug), you'd be right.

If the placebo isn't administered, the drug would not be the only variable that the treatment animals receive compared with the control animals. The extraneous variables introduced into the study are the injection itself and the drug vehicle, which may affect the results. For example, the injections could cause the animals stress each day, in which case the study would be investigating the effects of the drug and stress. However, if the control group received a daily injection as well, the investigators could conclude that any differences seen between the two groups were a result of the drug only.

## Blinding

How much will the participants and investigators know about the details of the experiment?

**Blinding refers to hiding certain information (e.g., group allocation) from one or more individuals involved in a research study.**

Blinding attempts to minimise or eliminate bias that may result if the participants or investigators know too much about the experimental conditions. As result, those involved in the research may unconsciously change their behaviour. Investigators may observe participants differently if they know they received the experimental drug rather than the placebo – this may bias the results. Participants may respond differently if they know they received the drug and not the placebo based on their pre-conceived ideas about what should happen.

Blinding is used in both control group and cross-over experimental designs. The best strategy is to blind as many individuals as possible in a research study. You may choose to have a single-blind or double-blind study.

**Bias is a process where the scientists performing the research or the participants of the research influence the results, in order to portray a certain outcome.**

### *Single-blind study*

In a single-blind experiment, the individual participants do not know which group they are in (control or treatment) and what intervention they will receive.

For example, in a study investigating the effects of caffeine ingestion on endurance running performance, participants don't know if they are taking caffeine or a placebo.


*Figure 2.5: Single-blind study. Icon by Antom5 used under a CC-BY 2.0 licence.*

### *Double-blind study*

In a double-blind experiment, the individual participants and the persons administering the experiment are unaware of critical aspects of the experiment, with this information being held by a third party, and is only revealed to the investigators when the study is over. A double-blind procedure is used to protect against both placebo effects and investigator bias.


*Figure 2.6: Double-blind study. Icon by Antom5 used under a CC-BY 2.0 licence.*

For example, in a study investigating the effects of caffeine ingestion on endurance running performance, the participants and the investigators don't know who is taking placebo and who is taking caffeine at the time of ingestion.

## Animal subjects and human participants

When physiologists experiment to learn more about humans, it may surprise you to hear that we often use animal subjects as well as human participants. Of the laboratory animals that we use for research, 95% are mice and rats. Laboratory mice and rats make an ideal model to study human physiology because:

- their genetic, biological and behavioural characteristics closely resemble those of humans
- many human disease states can be replicated in these animals
- they are inexpensive, and easy to handle and house
- they have a short-life span
- they are almost genetically identical – apart from sex differences – because they are usually inbred.

Genetic similarity greatly reduces the risk of introducing extraneous variables into the study and is the reason why random assignment is an appropriate method for creating groups. Group size would typically be around 10 animals, although this may differ depending on techniques used. It is standard practice to use the same strain sex and age of animal in any given study.

Animal studies usually have a control group experimental design, because these types of experiments are often terminal for the animals.

Human studies are not as straightforward and may vary widely – experiments may have 5–10 participants per group, and up to 1000s when longitudinal analyses or meta-analyses are carried out. Reading the current

literature on your topic will give you an indication of how many study participants are commonly required in your area of research.

There is likely to be much greater genetic variation among study participants, as well as differences in lifestyle factors (e.g. different diets and levels of exercise, and some people smoke). Because of these differences in humans, it becomes crucial when using control group experimental designs to balance groups, to try and limit the number of extraneous variables introduced to the study.

The size of the expected effect of the phenomena you are investigating is important. If you are investigating something that is likely to have a small effect, you will need more subjects or participants than if you are studying something that is likely to have a large effect. An investigator will conduct a power analysis when designing their study. A power analysis is a statistical approach used to determine the minimum number of subjects or participants required so you can reasonably expect to detect an effect of a given size.

## 2.3 EXAMPLES OF EXPERIMENTAL DESIGN IN HUMAN PHYSIOLOGY

The following sections are examples of human participant studies using different experimental designs. To determine if there are significant differences between your two groups after collecting the data (datasets), you will need to perform a statistical analysis. The experimental design that you choose will determine which statistical test you should use.

**Chapter 3** tells you how to do these statistical analyses.

### Control group experimental design

#### *Two experimental groups*

##### Example of a study of animal subjects using control group experimental design

An example of a control group experimental design is shown in **Figure 2.7**.

**Aim:** To determine the effect of an immunosuppressive drug (independent variable) on blood vessel function (dependent variable).

**Experiment:** A group of animals is randomly assigned to either a control or treatment group, with each group containing equal numbers. All animals are housed under the same conditions, but the treatment group animals receive the drug and the control group receives a placebo.

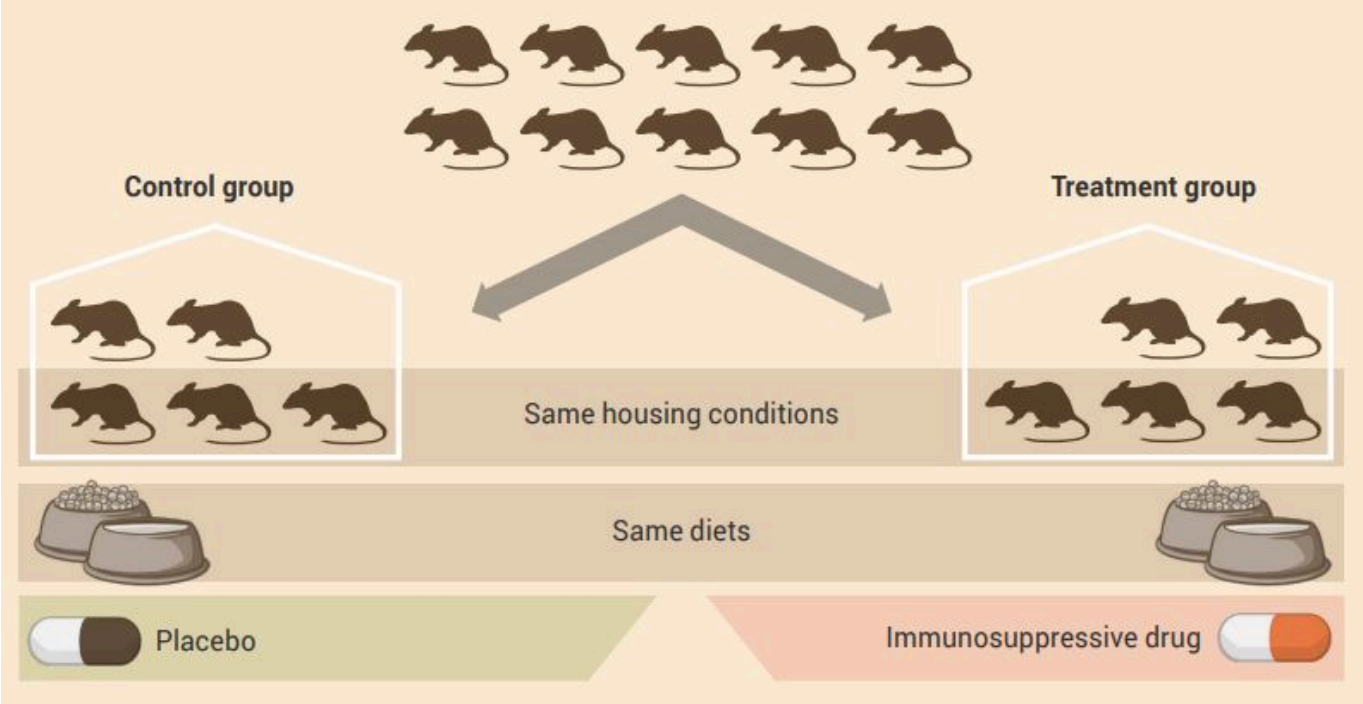


*Figure 2.7: Example of a study using control group experimental design to determine the effect of an immunosuppressive drug on blood vessel function in animal subjects.* ***Note:*** *Numbers of animal subjects for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Example of a study of human participants using control group experimental design

An example of a control group experimental design for human participants is shown in **Figure 2.8.**

**Aim:** To investigate and determine the effect of gender on exercise performance.

**Experiment:** Human participants are assigned to either a male or female group. All participants experience the same conditions – the difference is their gender (independent variable).

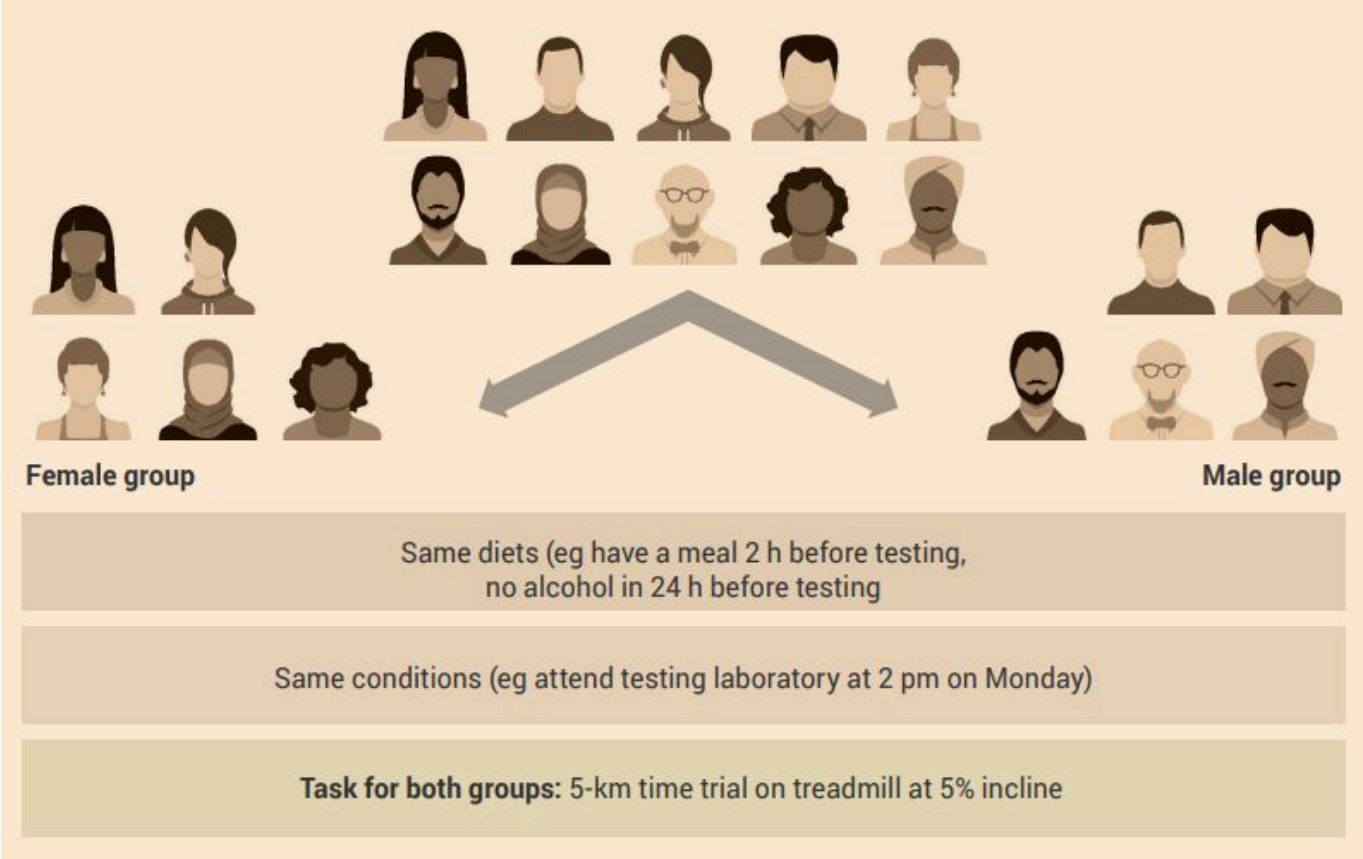


*Figure 2.8: Example of a study using control group experimental design to determine the effect of gender on aerobic running exercise performance in human participants.* ***Note:*** *Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

For **Figure 2.7** and **Figure 2.8** use an independent t-test to compare the measurements (dependent variables) from the two groups (conditions). By doing this, you will determine the effect of the independent variable on the dependent variable(s).

## *More than two experimental groups*

### Example of a study of animal subjects using control group experimental design

An example of a control group experimental design with more than two experimental groups is shown in **Figure 2.9.**

**Aim:** To determine the effect of chronic administration of two doses (moderate and high) of growth hormone (independent variable) on muscle size (dependent variable).

**Experiment:**

- The control group receives daily administration of a placebo.
- Treatment group 1 receives daily administration of the moderate dose of growth hormone.
- Treatment group 2 receives daily administration of the high dose of growth hormone.

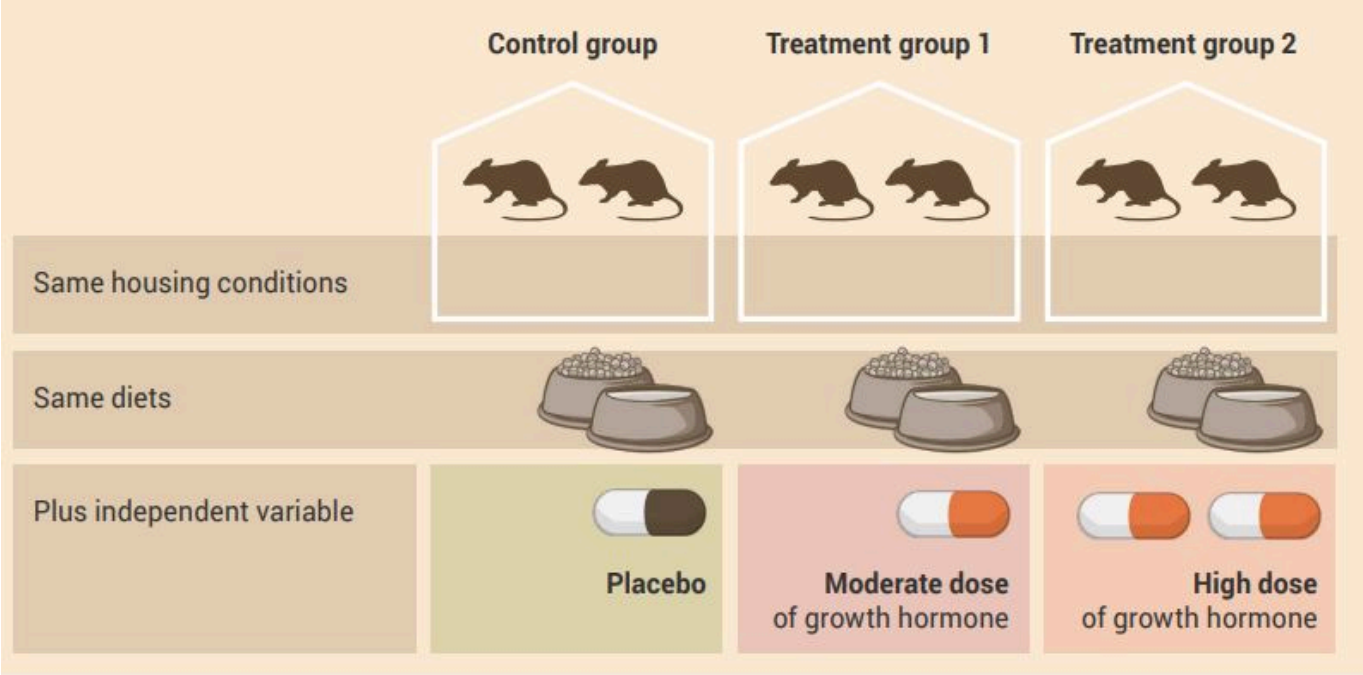


*Figure 2.9: Example of a study using control group experimental design to determine the effect of moderate dose growth hormone and high dose growth hormone on muscle mass in animal subjects. Note: Numbers of animal subjects for illustration purposes only. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Example of a study of human participants using control group experimental design

An example of a control group experimental design with more than two experimental groups is shown in **Figure 2.10.**

**Aim:** To determine the effect of different amounts of touch-typing practice (independent variable) on touch-typing skill development (dependent variable).

**Experiment:** In this case, a cross-over design would be inappropriate. Because of the learning effect of the treatment, an extraneous variable is introduced.

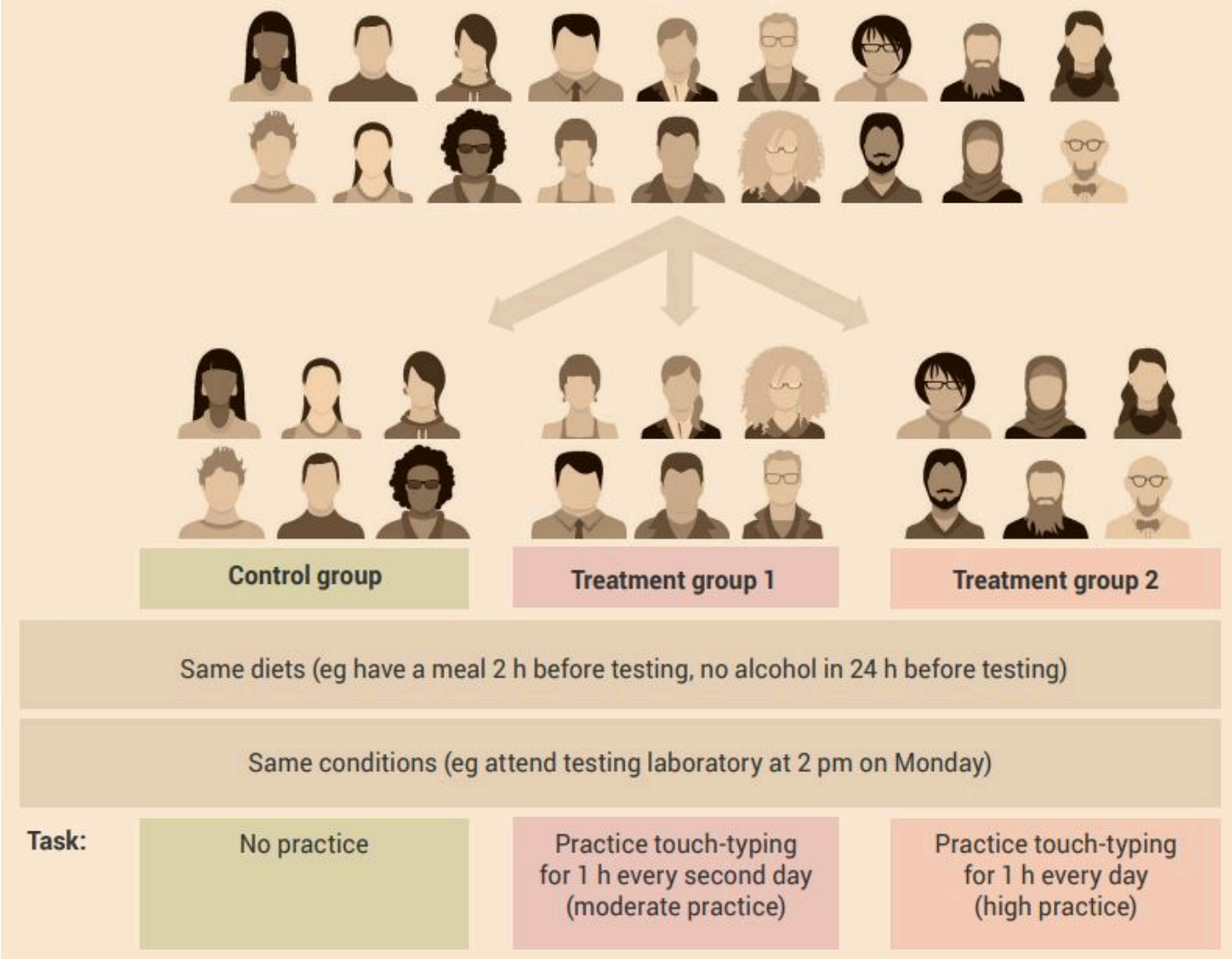


*Figure 2.10: Example of a study using control group experimental design to determine the effect of moderate practice and high practice on development of touch-typing skill in human participants who have never learnt to touch type.* ***Note:*** *Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

For **Figure 2.9** and **Figure 2.10** use a one-factor analysis of variance (ANOVA) independent samples test to compare the measurements (dependent variables) made in the three or more groups. By doing this, you will determine the effect of the independent variable on the dependent variable.

If the ANOVA reveals statistical significance between the groups, conduct a post hoc test to determine where the statistically significant differences exist (e.g. in **Figures 2.9** and **Figure 2.10**, there could be significant differences in the dependent variable between the control and treatment group 1, the control and treatment group 2, and/or treatment groups 1 and 2).

## Treatment order control / cross-over experimental design

### *Two experimental groups*

#### Example of a study of human participants using treatment order control / cross-over experimental design

An example of a cross-over experimental design is shown in **Figure 2.11.**

**Aim:** To determine the effect of caffeine on cognitive performance.

**Experiment:** A group of participants have their cognitive performance measured after consuming either caffeine or placebo on two test days, separated by at least seven days.

In week 1:

- group 1 participants consume the placebo
- group 2 participants consume caffeine before cognitive testing.

In week 2, the reverse happens:

- group 1 consumes caffeine before cognitive testing
- group 2 consumes placebo before cognitive testing.

Caffeine is usually eliminated from the body in under two days, so there would not be a carry-over effect of caffeine in group 2 participants one week after initial testing when the second session of testing occurs.

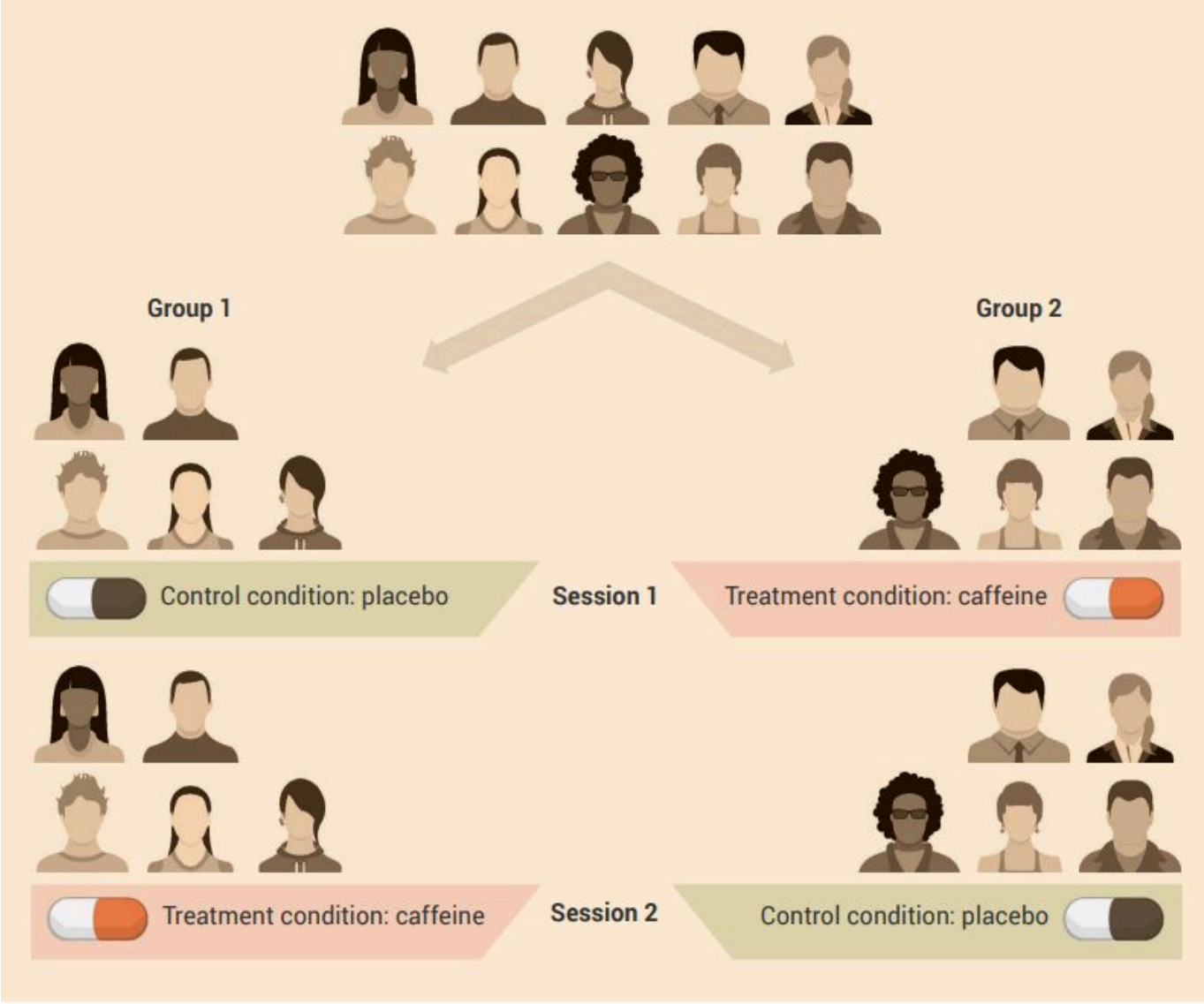


*Figure 2.11: Example of a study using treatment order control / cross-over experimental design to determine the effect of caffeine on cognitive function in human participants.* ***Note:*** *Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Use a paired t-test to compare the measurements obtained in the two conditions.

To determine the effect of the independent variable, combine the data (dependent variable) from groups 1 and 2, and conduct a paired t-test.

### *More than two experimental groups*

#### Example of a study of human participants using treatment order control / cross-over experimental design

An example of a treatment order control / cross-over experimental design with more than two experimental conditions is shown in **Figure 2.12.**

**Aim:** To determine the effect of moderate and high doses of caffeine (independent variable) on the time it takes to complete a 5 km running trial (dependent variable).

**Experiment:** In this example, participants have their running performance measured after consuming either moderate- or high-dose caffeine, or placebo, on three test days, with testing separated by at least seven days.

In week 1:

- group 1 participants consume the placebo before the 5-km run
- group 2 participants consume moderate-dose caffeine before the 5-km run
- group 3 participants consume high-dose caffeine before the 5-km run.

In week 2:

- group 1 consumes high-dose caffeine before the 5-km run
- group 2 consumes placebo before the 5-km run
- group 3 consumes moderate-dose caffeine before the 5-km run.

In week 3:

- group 1 consumes moderate-dose caffeine before the 5-km run
- group 2 consumes high-dose caffeine before the 5-km run
- group 3 consumes placebo before the 5-km run.

Caffeine is eliminated from the body in less than two days, so there would not be a carry-over effect one week after testing.

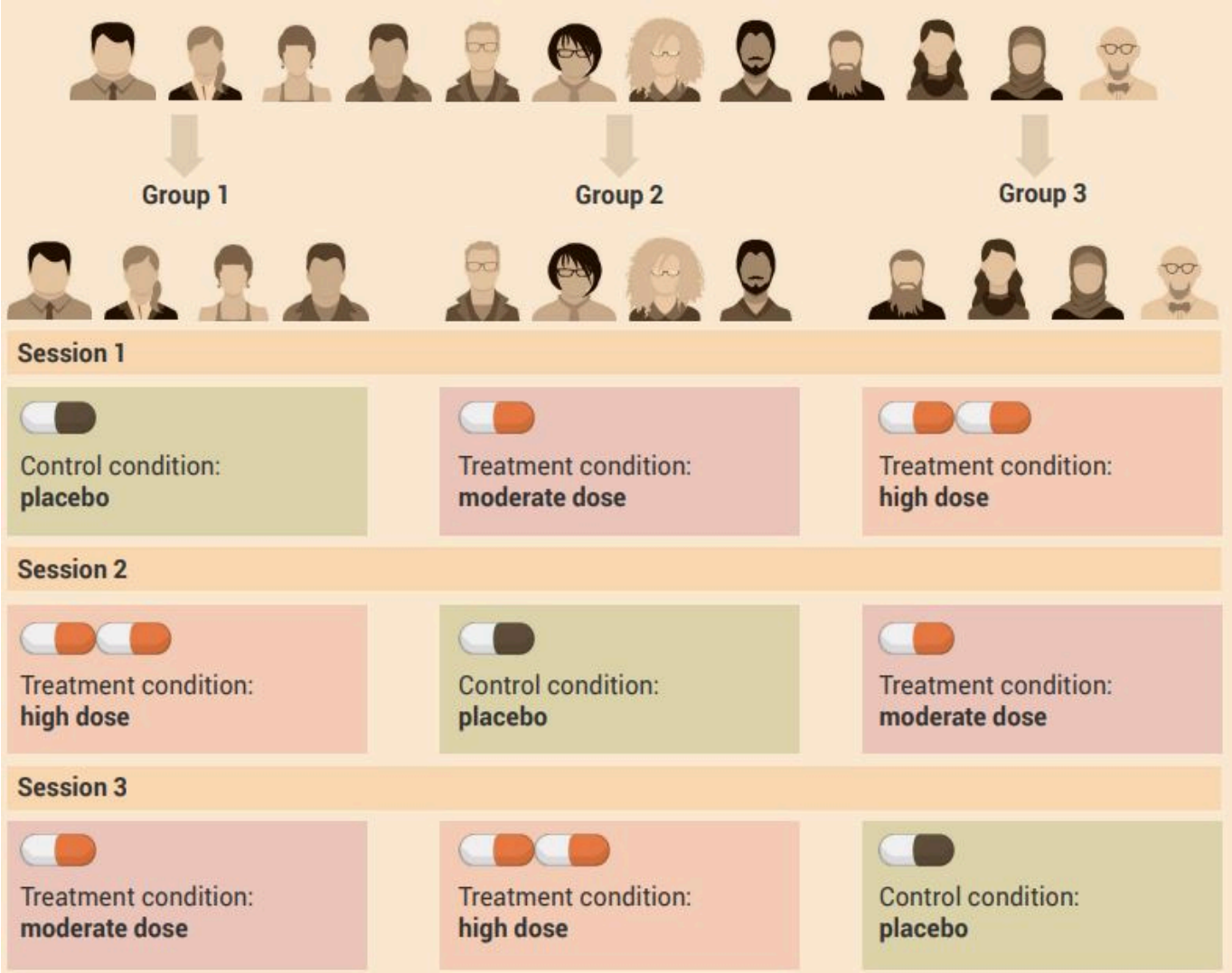


*Figure 2.12: Example of a study using treatment order control / cross-over experimental design to determine the effects of moderate and high dose caffeine on endurance running performance in human participants.* ***Note:*** *Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Use a one-factor analysis of variance (ANOVA) correlated samples test to compare the measurements (dependent variables) when there are at least three conditions. To determine the effect of the independent variable, combine the data (dependent variable) from all groups for each condition.

If the ANOVA reveals statistical significance between the groups, conduct a post hoc test to determine where the statistically significant differences exist (e.g. in **Figure 2.12**, there could be significant differences in the dependent variable between the control and experimental level 1, the control and experimental level 2, and/or experimental levels 1 and 2).

## Investigating the effect of multiple independent variables

You may wish to conduct a more complex experiment in which you are testing the effect of multiple independent variables, such as time (pre-test and post-test) and drug (placebo and drug).

### *Example of a study of human participants using control group experimental design where more than two independent variables are introduced*

An example of this experimental design is shown in **Figure 2.13** where the aim of the study is to investigate

the effect of an exercise program alone and the exercise program plus adoption of the Mediterranean diet on a group of patients who have suffered an adverse cardiovascular event. The two independent variables are the exercise program and the diet.

Long-term and ongoing adoption of the diet rules out the possibility of using a cross-over design.


*Figure 2.13: Example of a study using control group experimental design to determine the effect of diet and exercise intervention on the cardiovascular disease risk profile in human participants who have suffered a cardiovascular event.* ***Note:*** *Numbers of human participants for illustration purposes only.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Use a two-factor analysis of variance (ANOVA) independent measures test to compare the measurements (dependent variables) made in the three or more conditions. By doing this, you will determine the effects of the independent variables on the dependent variable.

When this study design is used, it is possible to find main effects and interaction effects. Main effects are significant differences in dependent variables caused by the independent variables. In this example, this means effects of diet and/or exercise on their own. Interaction effects are significant effects that result when independent variables are combined – in this example this means effects of diet and exercise together.

When the ANOVA finds significant main effects of one or more factors (independent variables), conduct a post hoc analysis to determine which differences are significant.

### *Example of a study of human participants using treatment order control / cross-over experimental design where more than two independent variables are introduced*

An example of this experimental design is shown in **Figure 2.14.**

**Aim:** To determine the effect of an acute bout of exercise alone, and exercise plus an acute dose of caffeine, improves short-term memory function in humans.

**Experiment:** The two independent variables are exercise and caffeine. The short-term effect of caffeine allows us to use a cross-over design. The participants and investigators can be blinded to caffeine, but not for exercise.

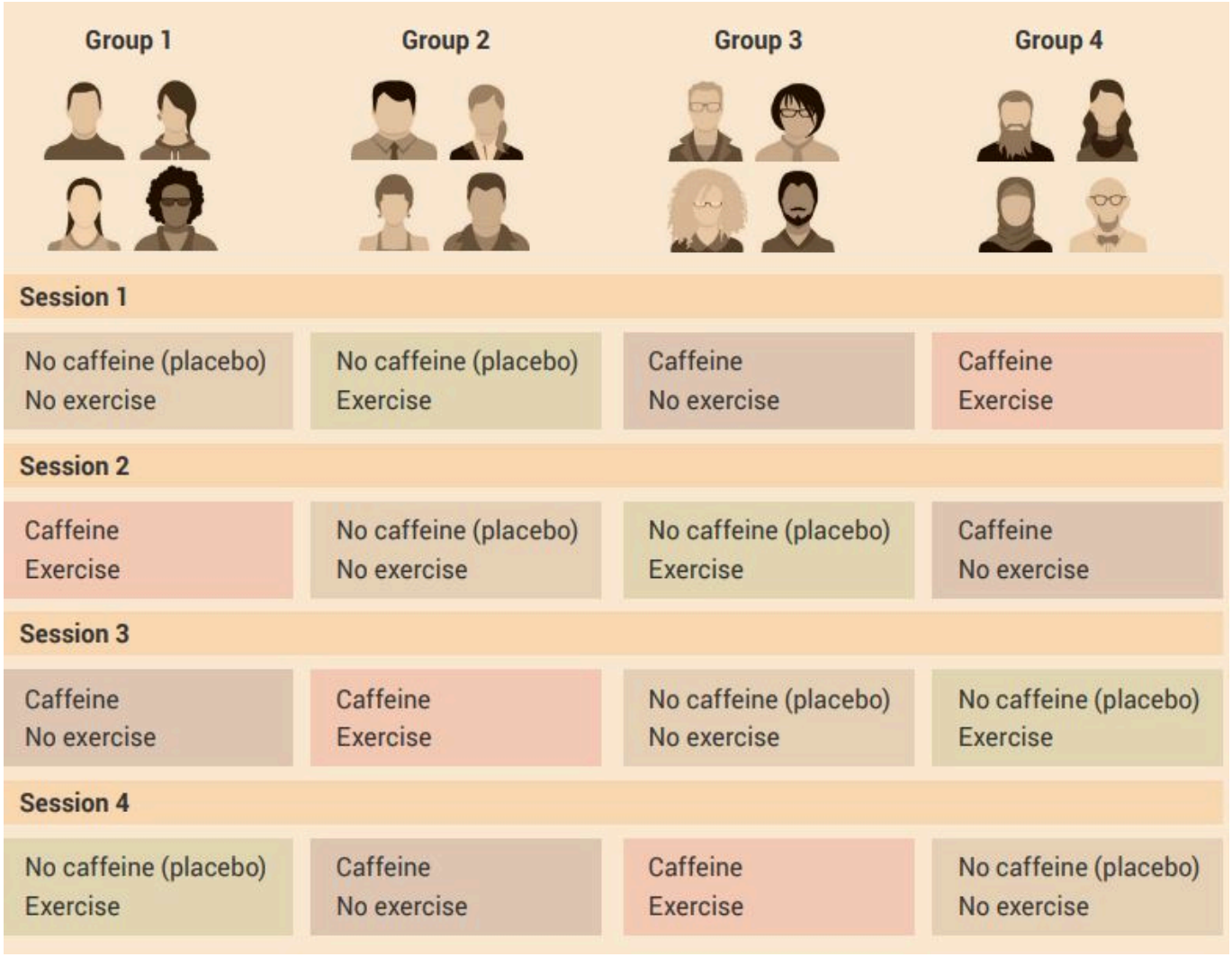


*Figure 2.14: Example of a study using treatment order control / cross-over experimental design to determine the effects of caffeine and exercise on short-term memory in human participants.* **Note:** *Numbers of human participants for illustration purposes only.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Use a two-factor analysis of variance (ANOVA) repeated measures test to compare the measurements (dependent variables) when there are at least two independent variables. To determine the effects of the independent variables, combine all data (dependent variable) from all groups for each condition.

When this study design is used, it is possible to find main effects and interaction effects. Main effects are significant differences in dependent variables caused by the independent variables. In this example, this means the effects of caffeine and/or exercise on their own. Interaction effects are significant effects that result when independent variables are combined – in this example, this means the effects of caffeine and exercise together.

When the ANOVA finds significant main effects of one or more factors (independent variables), conduct a post hoc analysis to determine which differences are significant.

All of this can be a bit overwhelming, so **Figure 2.15** is a flowchart that summarises how to decide which experimental design and statistical analysis to use. A clearer version of this flowchart [PDF] is available to download.

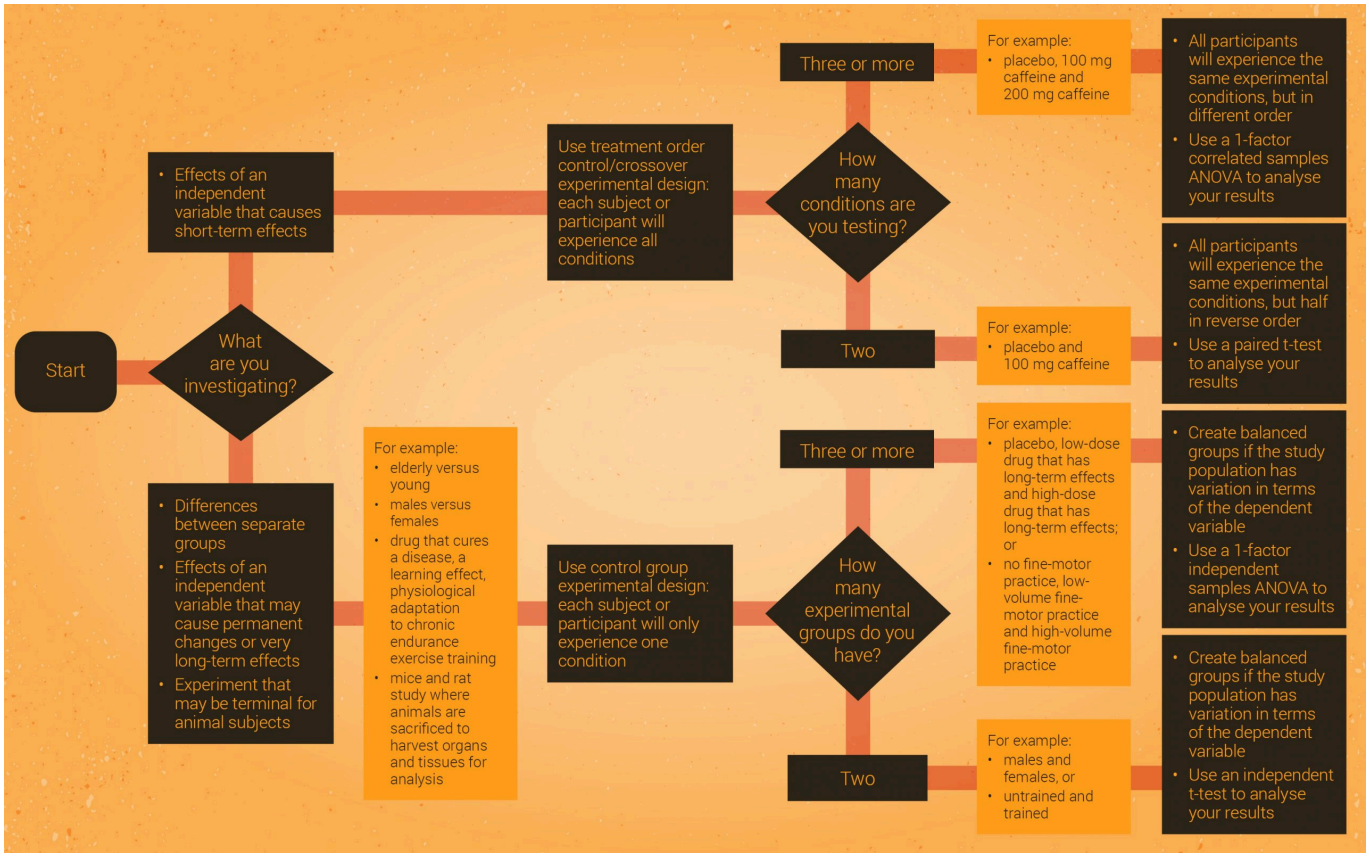


*Figure 2.15: How to choose the right experimental design.* ***Source:*** *Image by La Trobe University used under a CC BY-NC-SA 4.0 licence.*

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=74#h5p-4

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CHAPTER 3

# *Using Statistical Analyses*

> Statistics is the science that deals with the collection, analysis and interpretation of numerical data.

Statistics has entered almost every aspect of human endeavour. We can use it for better planning, more efficient delivery of services and increased productivity. Although statistics is a rewarding career choice, most of us will not specialise in this field.

It is, however, important to improve statistical literacy among scientists, journalists, doctors, patients and the community at large, so we can make informed decisions in the face of uncertainty.

In scientific research, we conduct statistical analyses to help us determine whether datasets are different from each other. When statistical analysis determines that datasets are different, we refer to the datasets as 'statistically different', or the difference as 'statistically significant' or that there is 'a significant difference'.

When statistical analysis reveals that datasets are not different, we say that there is 'no significant difference' between groups.

In this chapter, we will explain some of the basic statistical analyses student scientists will carry out – many of which were referred to in **Chapter 2** when you learned about designing experiments. This chapter also provided instructions for conducting these tests using Microsoft Excel software and the VassarStats website.

## 3.1 STATISTICS AS A PART OF EVERYDAY LIFE

### Cholera map made by John Snow in 1854

The location of reported cases of cholera are shown in **Figure 3.1.** Presentation of the data collected on the number of cases and where they occurred would have been very useful in understanding the spread of the disease and contributing to prevention.

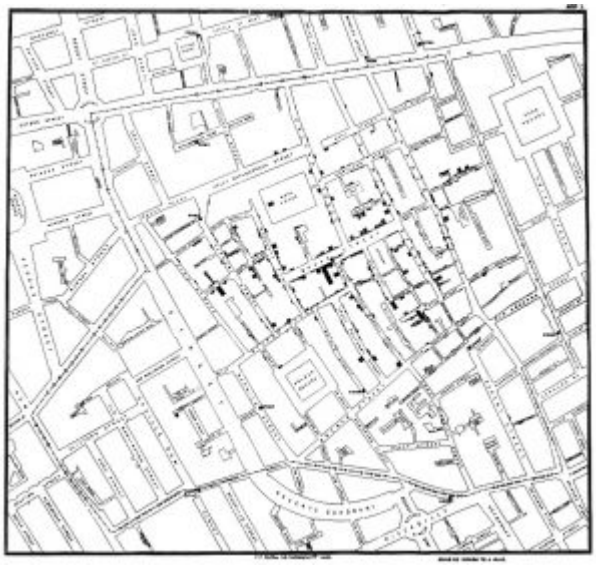

*Figure 3.1: Cases of cholera in London in 1854.* ***Source:*** *'Snow-cholera-map-1' by John Snow, used under CC0 1.0.*

### Sporting performance

**Figure 3.2** summarises the test bowling statistics of cricketer Imran Khan, showing the number of runs conceded each innings, and career and last 10-innings averages. Collecting so much information in one figure, combining raw data and averages, is a very economical way to summarise a sportsperson's career.

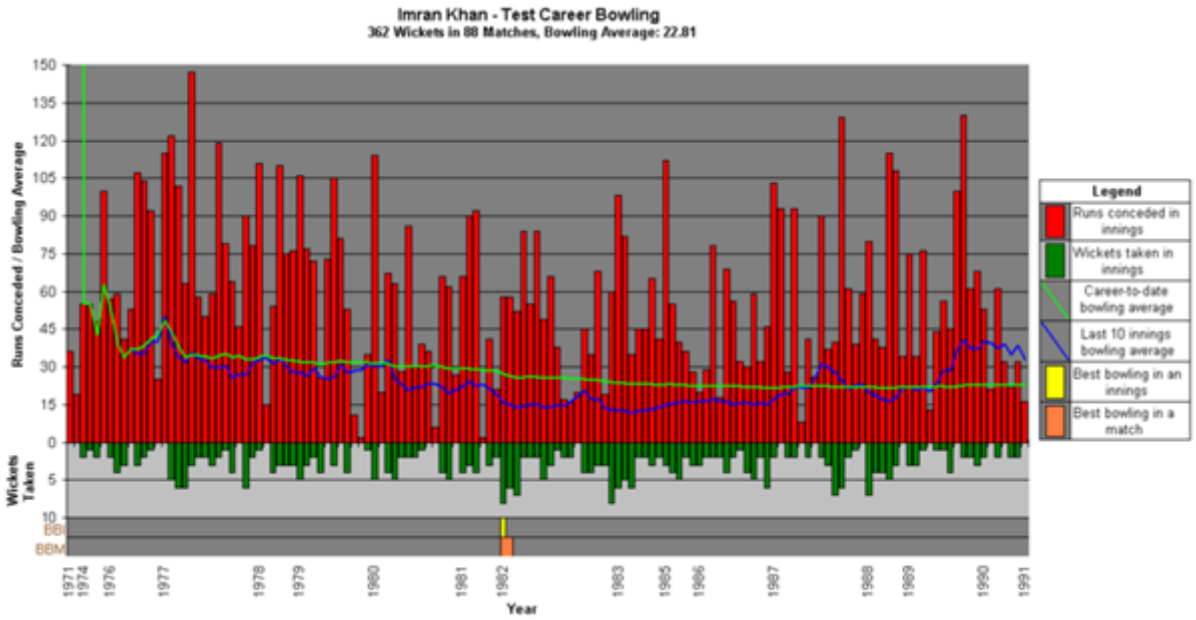


*Figure 3.2: Test bowling career statistics for Imran Khan (1971-1991). Source: 'Imran Khans bowling statistic' by Masai 162, used under CC0 1.0.*

## Health of the population

This bar graph shown in **Figure 3.3** presents the percentage of the population aged 60 years and over in 41 countries who have dementia . This figure provides the reader with details of the percentage of the population diagnosed with dementia at the same time allowing a comparison of the percentages across a number of countries.

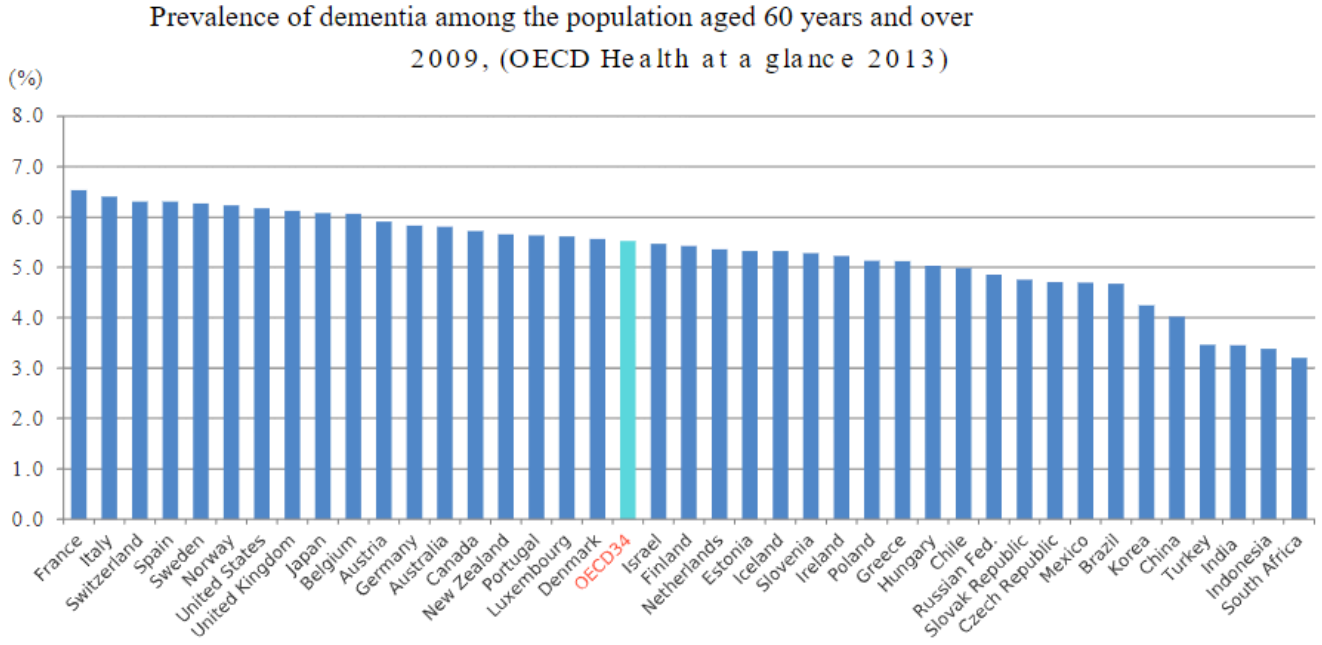


*Figure 3.3: Prevalence of dementia among people aged 60 years and over. Source: 'Oecd-dementia' by Yuasan, used under CC0 1.01.*

## 3.2 SETTING UP EXCEL FOR STATISTICAL ANALYSIS

Use the arrows below to find out how to set up excel for statistical analysis.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-6

## 3.3 CALCULATING DESCRIPTIVE STATISTICS USING EXCEL

Descriptive statistics are obtained to provide a simple summary of a dataset. Common summary values obtained are mean = a number that typifies a set of numbers, such as a geometric mean or an arithmetic mean; the average value of a set of numbers, and standard deviation = a statistic used as a measure of the dispersion or variation in a distribution; how much the data points differ from the mean.

Use the arrows below to find out to calculate descriptive statistics using Excel.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-8

## 3.4 MANUALLY CALCULATING MEAN AND STANDARD DEVIATION IN EXCEL

Use the arrows below to find out to manually calculate mean and standard deviation in Excel.

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https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-9

## 3.5 THE *P* VALUE

In scientific research, we refer to the *p* value to determine if there is a statistical difference (significant difference) between datasets.

Traditionally, in scientific research, a *p* value of less than 0.05 is considered significant (mean values are

different). A *p* value of 0.05 means that there is a 95% likelihood that the difference between the means is because of the experimental conditions and not chance. In other words, there is only a 5% likelihood that the difference between the means is because of chance, and not the treatment.

## One- and two-tailed tests

When you conduct statistical tests using Excel (and most other statistics software) you will see in the outputs that there are two *p* values, one for a **one-tail test**, and the other for a **two-tail test**; **the values will be different.**

A two-tailed test, also known as a non-directional hypothesis, is the standard test of significance to determine if there is a relationship between variables in either direction. A one-tailed test, also known as a directional hypothesis, is a test of significance to determine if there is a relationship between the variables in one direction. A one-tailed test is useful if you have a good idea, usually based on your knowledge of the subject, of the direction of the difference that exists between variables. This makes our statistics more sensitive and able to detect more-subtle differences.

Unless you can justify why you are using a one-tail test, it is recommended that you use a two-tail test.

Video 3.1: p value in statistics [4 mins, 42 secs]

The video below explains what a p value tells us. There are different types of statistical tests used to determine the p value, depending on the type of data you have.

**Note:** Closed captions are available by selecting the CC button below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=123#oembed-1

## Calculating the *p* value using an independent t-test in Excel

This statistical hypothesis test is conducted to determine whether there is a statistically significant difference between the means in two ***unrelated*** groups (e.g. females and males).

Use the arrows below to find out to calculate the p value using an independent t-test in Excel.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-10

## Calculating the *p* value using a paired t-test in Excel

This statistical hypothesis test is conducted to determine whether there is a statistically significant difference between the means in two ***related*** groups (e.g. control and treatment measures in a group of participants in an experiment using a cross-over design).

Use the arrows below to find out to calculate the p value using a paired t-test in Excel.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-11

## Calculating the *p* value using a one-factor analysis of variance (ANOVA)

The one-factor analysis of variance (ANOVA) test is conducted to determine whether there is a statistically significant difference between the means of **three or more** groups. The groups may be independent or unrelated, or they may be related.

Unrelated groups are made up of separate groups where a given participant will only experience one condition in a control group experimental design (e.g. children, adults and older people).

Related groups are made up of the same participants with each participant experiencing all conditions as would occur in a cross-over experimental design (e.g. placebo, acute low-dose caffeine, acute high-dose caffeine).

In Excel, the same test is used to determine if there are significant differences between groups. It doesn't matter if the groups are independent or related. (But note that this is not the case with all analytic tools).

Use the arrows below to find out to calculate the p value using a one-factor analysis of variance (ANOVA).

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-12

To determine which datasets are statistically different from each other, conduct independent t-tests (using the instructions shown previously) comparing variable 1 and variable 2, variable 2 and variable 3, and variable 1 and variable 3.

This is not the ideal way to conduct a post hoc analysis, but is the simplest way to do this using Excel. We suggest using VassarStats for one-factor ANOVA tests.

## 3.6 LINEAR CORRELATION

### When do I use a linear correlation?

You may choose to use correlation when you are trying to determine whether, and how strongly, two variables are related (linearly). Correlations are appropriate to use when your data are **continuous**, which means that the values are not restricted to defined separate values but can be any value across an endless range. Examples of continuous data include temperature in degrees Celsius and height in centimetres. (Note, data should be normally distributed and not contain any significant outliers if you plan to test for correlations; these factors are not addressed in this guide.)

> Correlation is a statistical approach to determining if and how well two variables are related to each other.

One of the simpler correlations is called Pearson's product-moment correlation. This test produces a **correlation coefficient**, *r*, which is the number that indicates the strength or magnitude, and the direction of the relation between the two variables. The correlation attempts to draw a line of best fit through the data points, and *r* indicates how far away the data points are from the line. There are different guidelines for interpretation of the strength of the relation – one example is shown in **Figure 3.4.**

Generally speaking, the more the relation between the two variables looks like a straight line, the closer *r* gets to 1.0 or –1.0. If *r* is positive then you have a direct or increasing relation between variables and if *r* is negative then you have an inverse or decreasing relation between variables.

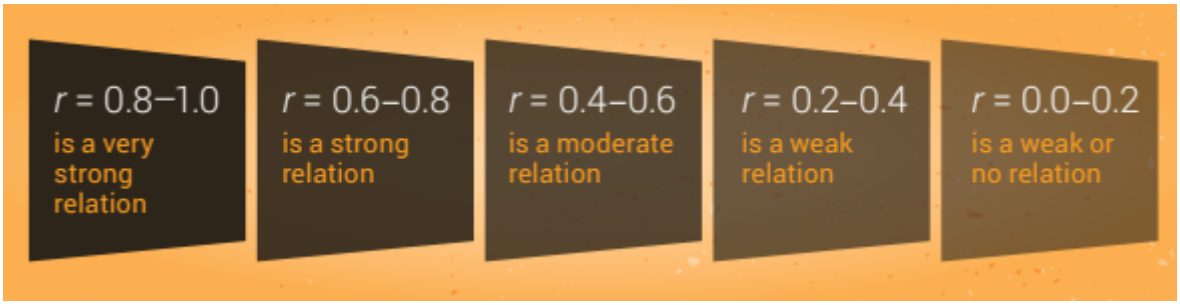



*Figure 3.4: How to interpret the size of a correlation. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Remember that correlation does not indicate causation. Finding a correlation between two data points does not mean that one caused the other. **Box 3.1** gives a more detailed explanation of this.

Box 3.1: Difference between correlation and causation

A physiological example of the difference between correlation and causes can be seen in heart disease studies.

**Correlation studies**

There are a lot of epidemiologic studies showing **inverse associations** between antioxidant intake and the incidence of atherosclerosis. In other words, an **inverse correlation** exists between antioxidant intake and the incidence of atherosclerosis. Because the epidemiologic data only show a correlation however, it would be **incorrect** to say that 'low antioxidant intake **causes** atherosclerosis' based on these studies.

Similarly, a number of early studies showed that low concentrations of blood antioxidants were **associated** with an increased risk of adverse cardiac events. In other words, there was an **inverse correlation** between blood antioxidants and adverse cardiac events. Because correlation does not indicate causation, the authors of this group of **studies could not conclude** that low blood antioxidants **caused** adverse cardiac events, or vice versa.

**Cause-and-effect studies**

Follow-up studies went further than looking for correlation between these variables. Experiments were designed to determine **the effect**

of antioxidant supplementation on atherosclerosis and adverse cardiac events. To determine **cause-and-effect,** groups of investigators designed randomised controlled trials (RCTs) where one group of human participants received long-term antioxidant supplementation, and the other group received a placebo.

Overall, these studies have shown conflicting findings, with some studies showing that antioxidant supplementation **reduced** atherosclerosis and adverse cardiac events, and other studies showed **no effect**. The exact reasons for the contradictory findings observed in the RCTs are not known, although it has been suggested that differences in the study populations, supplements administered, and outcome measures may explain the variability.

A key point that you should take from this example is that these later experiments were specifically designed to determine if **cause-and-effect** exists. In this case, it would be **incorrect** to talk about **associations or correlations** between antioxidant intake and atherosclerosis and adverse cardiac events.

### Case study 3.1: Example of correlation analysis

Wisløff and colleagues investigated whether maximal strength was related to sprint performance in elite male soccer players. The first variable, maximal strength, was the maximum load the participants could lift in half squats (1 repetition maximum, in kilograms). The second variable, sprint performance, was time taken to sprint 10 m (10 m sprint, in seconds). The scatter plot revealed a direct linear relation and this was supported by the correlation coefficient and the *p* value: $r = 0.94$, $p < 0.001$. According to the *r* value, the direct linear relation was very strong (see images below). The investigators concluded that maximal strength in half squats was associated with sprint performance – participants with high strength ran 10 m faster than participants with low strength.

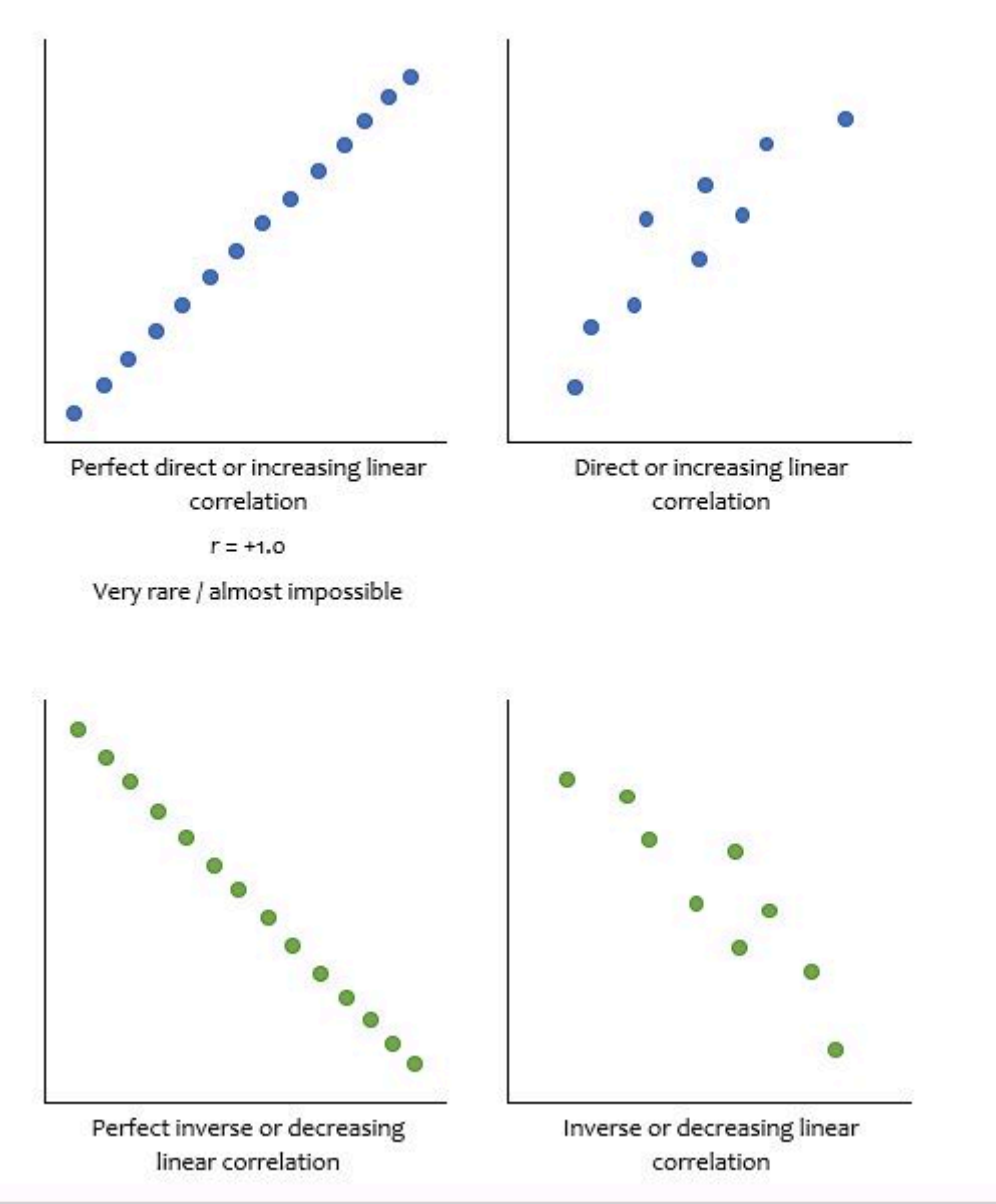



*Figure 3.5: Possible associations between 2 variables.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Testing for a correlation using Excel

We will look at the steps to follow for a correlation using the example of investigating whether time spent exercising per week was associated with performance on physiology exams.

Use the arrows below to test for a correlation in Excel.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-13

### Reporting the results of the correlation

If you did not test the significance, then:

*r*(df) = [Pearson coefficient]

Where df = total number of observations / data points – 1

Using the example above. *r*(9) = 0.87

If you did test the significance, then:

*r*(df) = [Pearson coefficient], *p* = [*p* value]

Using the example above. *r*(9) = -0.87, *p* = 0.001

Excel will not easily test the significance of a correlation; however, if you are using more powerful statistical software (or VassarStats), you will obtain a p value that you can interpret as previously discussed.

When describing and discussing your data, you can refer to the strength of the relation between the variables using the wording shown in **Figure 3.4**; the direction will be determined by whether *r* is positive or negative.

In this example:

A very strong direct relation (r=???) was observed between time spent exercising per week and performance on a physiology exam.

Remember, you cannot conclude that long periods of time spent exercising caused high performance on a physiology exam, or vice versa, just that these variables are associated with each other.

## 3.7 VASSARSTATS

VassarStats is a free web-based program that you can use to conduct statistical analysis. We recommend using this program for one-factor ANOVA, two-factor ANOVA and linear correlations. Unlike Excel, VassarStats allows you to conduct post hoc tests after your ANOVA and to determine the statistical significance of linear correlations. It is a simple to use website that steps you through each phase of the test.

Use VassarStats to calculate ANOVA and linear correlations.

If you use VassarStats to conduct one-factor ANOVA tests, use the following:

- Independent group comparison: One-factor ANOVA Independent Samples test
- Related group comparison: One-factor ANOVA Correlated Samples test.

The designers of this site suggest using the following web browsers – Firefox, Safari, and Chrome. Note that Internet Explorer is not recommended.

Below are instructions for using VassarStats to conduct the following tests:

- One-factor ANOVA Independent Samples
- One-factor ANOVA Correlated Samples
- Linear regression.

## Calculating the *p* value using a one-factor analysis of variance (ANOVA) Independent Samples test

This statistical hypothesis test can be used to determine whether there is a statistically significant difference between the means of **three or more** groups when the groups are independent or unrelated.

Unrelated groups are made up of separate groups where a given participant will only experience one condition in a control group experimental design – for example, children, adults and older participants.

All screenshots in this section are used with permission from the copyright owner, Richard Lowry.

Use the arrows to learn how to calculate the p value using a one-factor analysis of variance (ANOVA) Independent Samples test.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-15

## Calculating the *p* value using a one-factor analysis of variance (ANOVA) Correlated Samples test

This statistical hypothesis test can be used to determine whether there is a statistically significant difference between the means of **three or more** groups when the groups are related or made up of the same participants.

Related groups are made up of the same participants, with each participant experiencing all conditions as would occur in a cross-over experimental design – for example, placebo, acute low-dose caffeine, acute high-dose caffeine.

All screenshots in this section are used with permission from the copyright owner, Richard Lowry.

Use the arrows to learn how to calculate the p value using a one-factor analysis of variance (ANOVA) Correlated Samples test.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-16

## Testing for a correlation using VassarStats

We will now look at the steps to follow if trying to determine correlation, using the example of investigating whether time spent exercising per week was associated with performance on physiology exams in the section called 'Testing for a correlation using Excel'.

All screenshots in this section are used with permission from the copyright owner, Richard Lowry.

Use the arrows to learn how test a correlation using VassarStats.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-17

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=123#h5p-18

CHAPTER 4

# *Data Visualisation*

Now that you are familiar with the scientific method, know how to design experiments, and have collected and analysed the results, what do you do next?

By the time you arrive at this stage, you will know your research project and data inside out. Other than your immediate colleagues, most people will not be as familiar with the work. You know that a part of the scientific process is sharing information.

You will increase the chance of engaging and informing your audience by communicating the findings of your research visually, through figures and tables. Presenting data in figures and tables, rather than in text alone, will help the audience grasp difficult concepts and observe patterns. You saw some good examples of these in **Section 3.1.**

In this chapter, you will learn how to create column and line graphs (figures) with correct axis titles, error bars, and significance symbols using Microsoft Excel and Word software. You will also learn how to create scientific tables.

## 4.1 CREATING A COLUMN GRAPH IN EXCEL

Column or bar graphs are used to show patterns and relationships across and between datasets when the general pattern is more important than the exact data values.

Start by calculating descriptive statistics (mean, standard deviation) using one of the methods shown in **Chapter 3.**

Use the arrows below to learn how to create a column graph in Excel.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=161#h5p-19

Box 4.1: Using the 'Charts elements' feature

You can use this menu to change how your graph looks and what data are displayed.

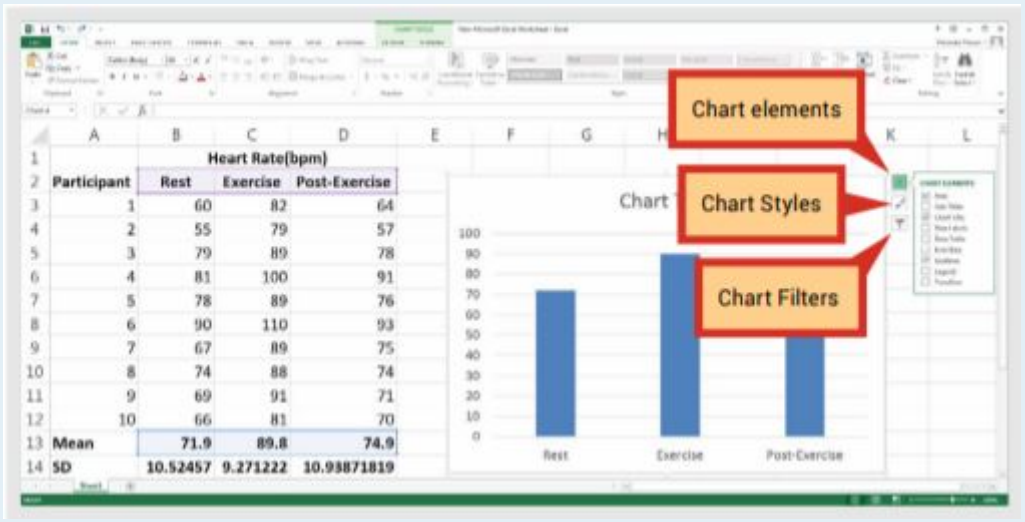



*Figure 4.1: Menu of graph features.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Changing axes and axes titles

If you untick the box next to '**Axes'**, you can remove both the x- and y-axes. If you hover your mouse over the '**Axes item**', you can access more options for formatting the axes.

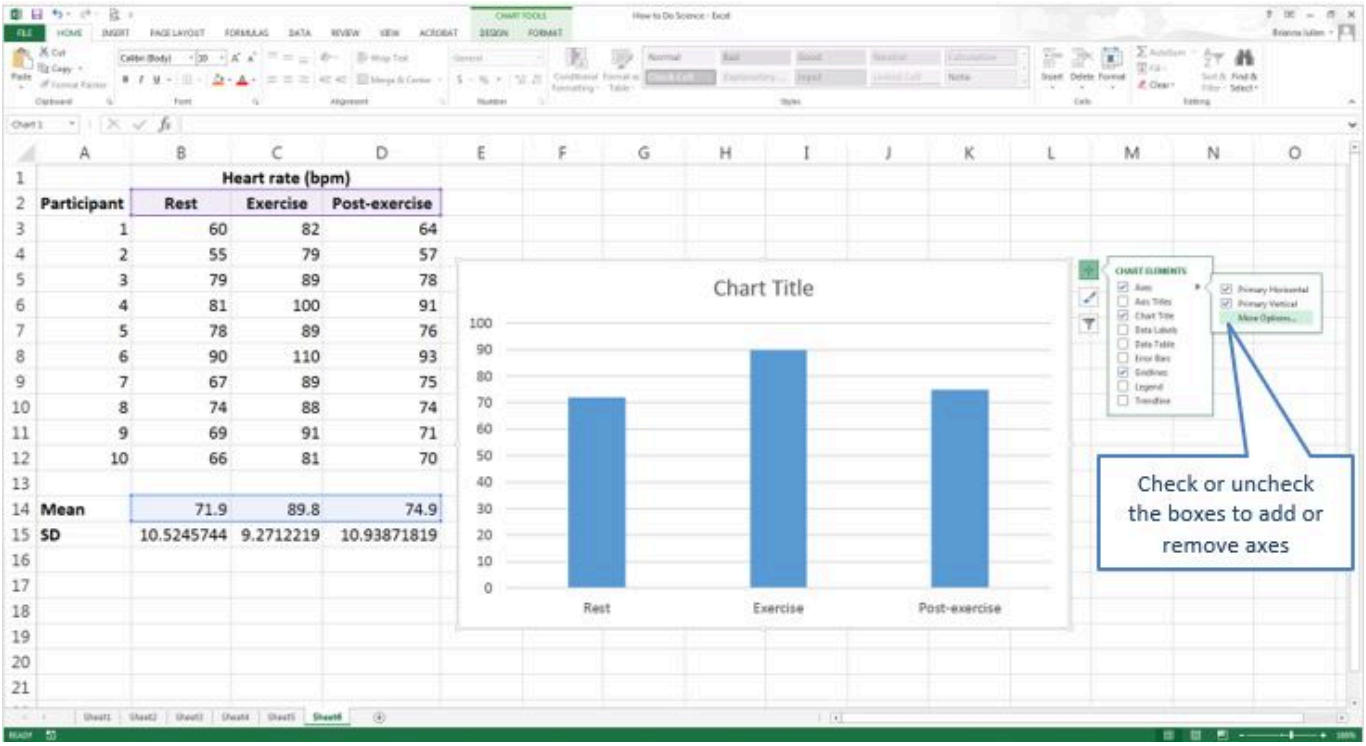



*Figure 4.2: Add and removing axes.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Add axis titles and format the titles. If you selected column headings when creating the graph, each column will already be labelled with that information (rest, exercise and post-exercise in this example).

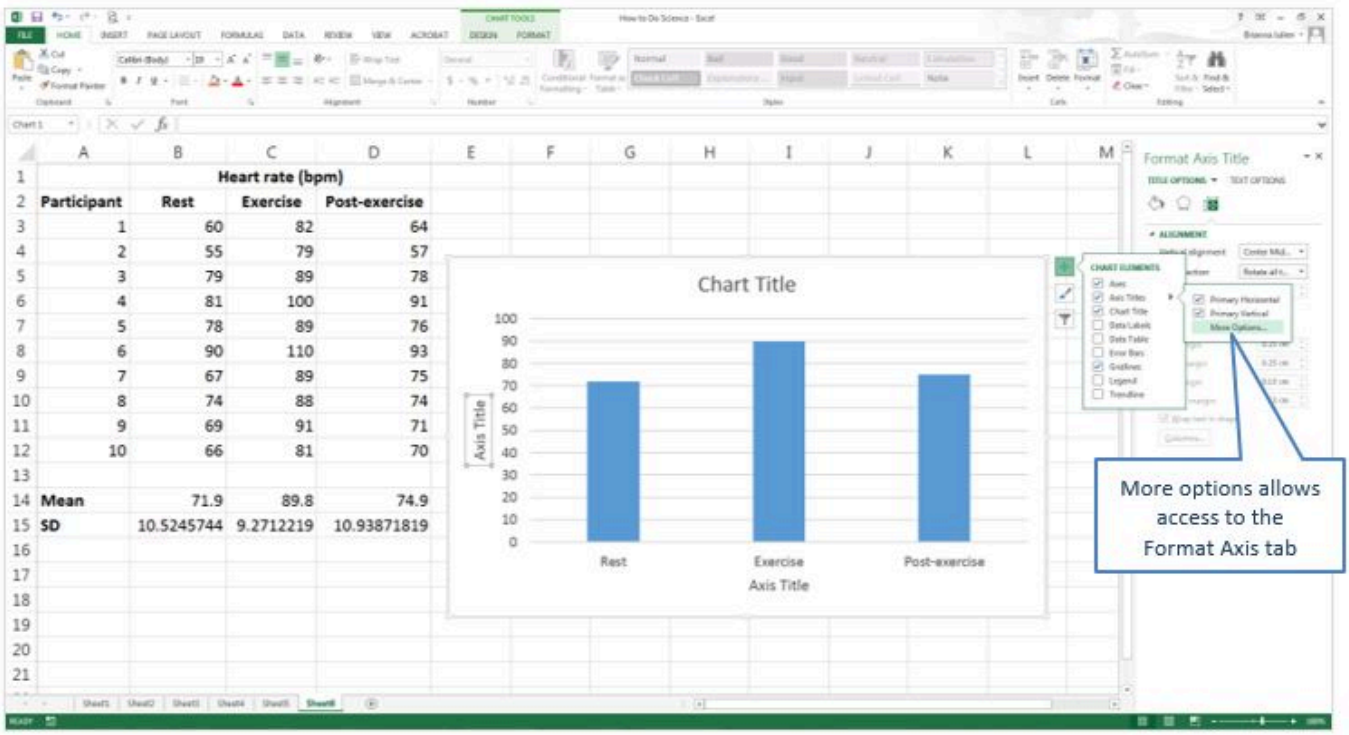



*Figure 4.3: Format access tab. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

When the '**Axis Titles**' box is checked, generic axis labels will be added. Right-click on the labels and select '**Edit Text**' to replace the generic title with your own.

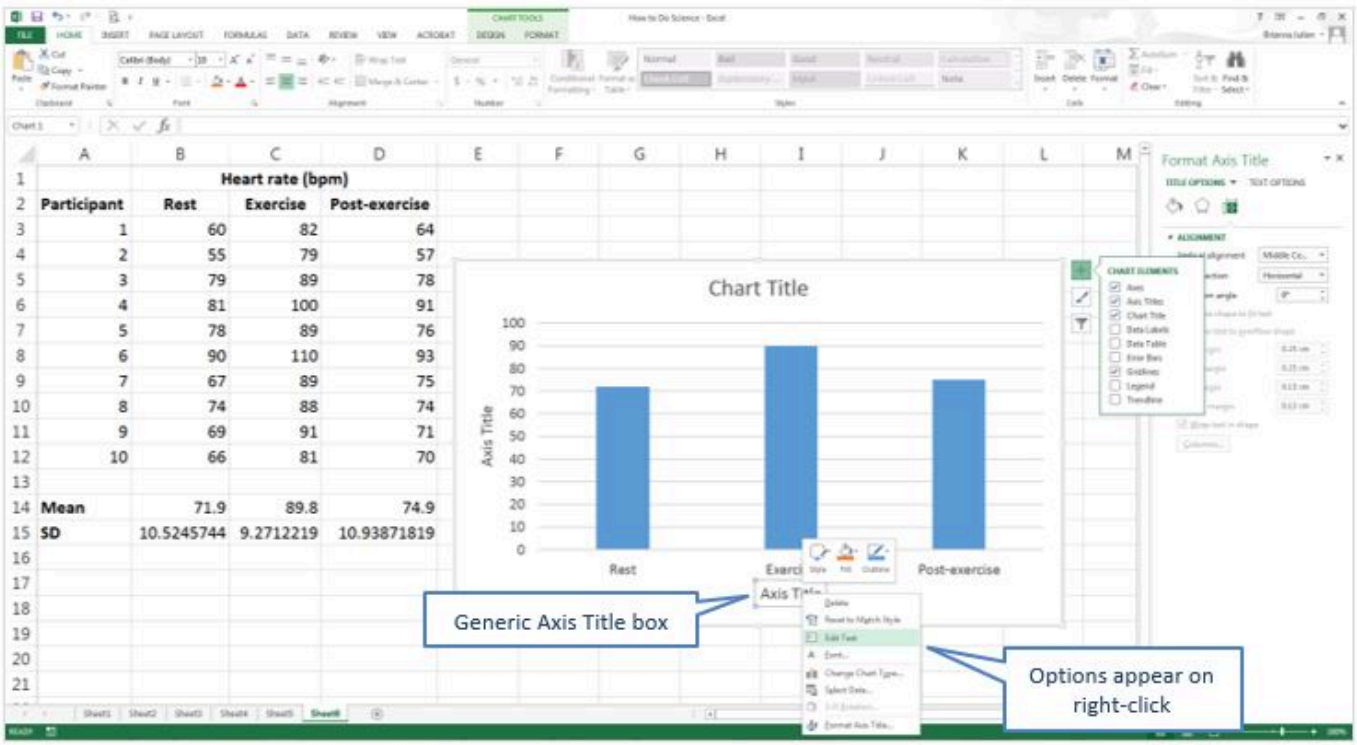



*Figure 4.4: Axis titles box. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Deleting the chart title

In most cases, you will not need a chart title because this information will be provided in the figure name or caption, so uncheck the box next to **'Chart Title'.**

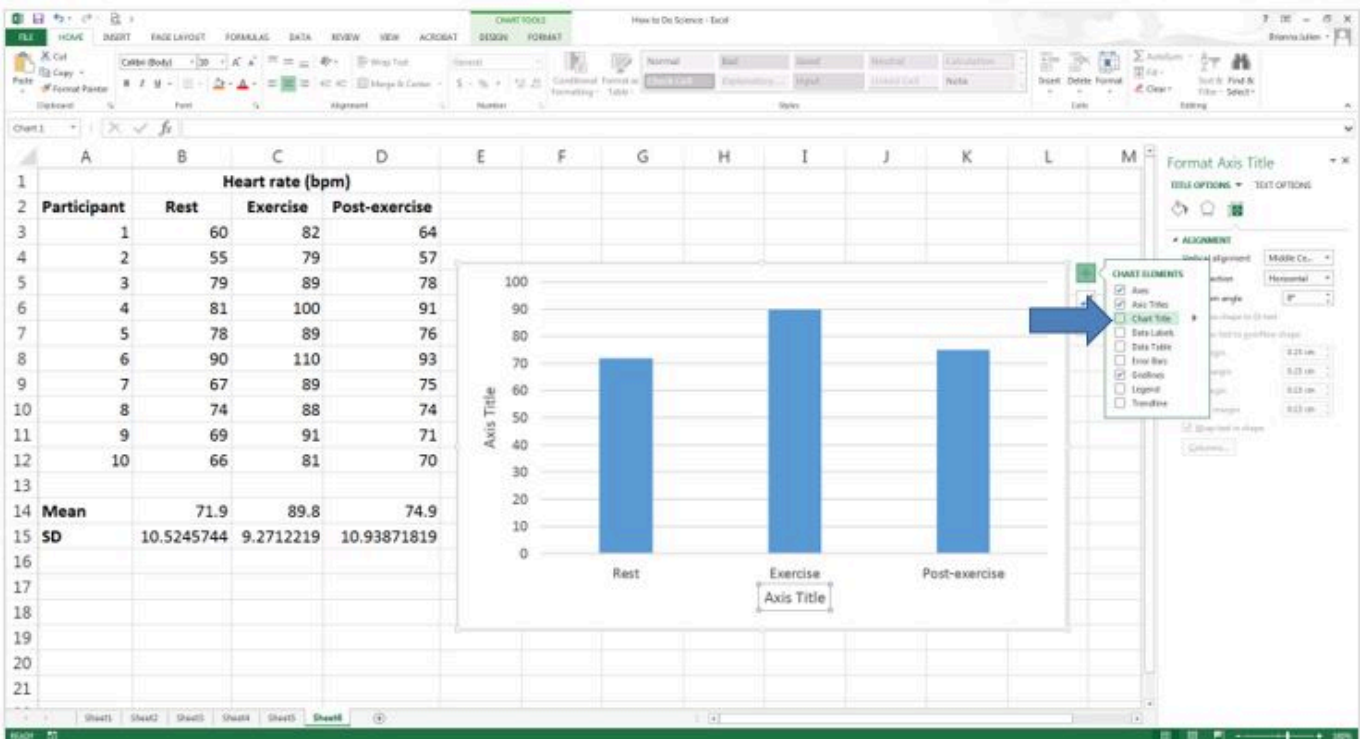



*Figure 4.5: Deleting the chart title.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Adding or removing gridlines

Check or uncheck the **'Gridlines'** box to add or remove gridlines.

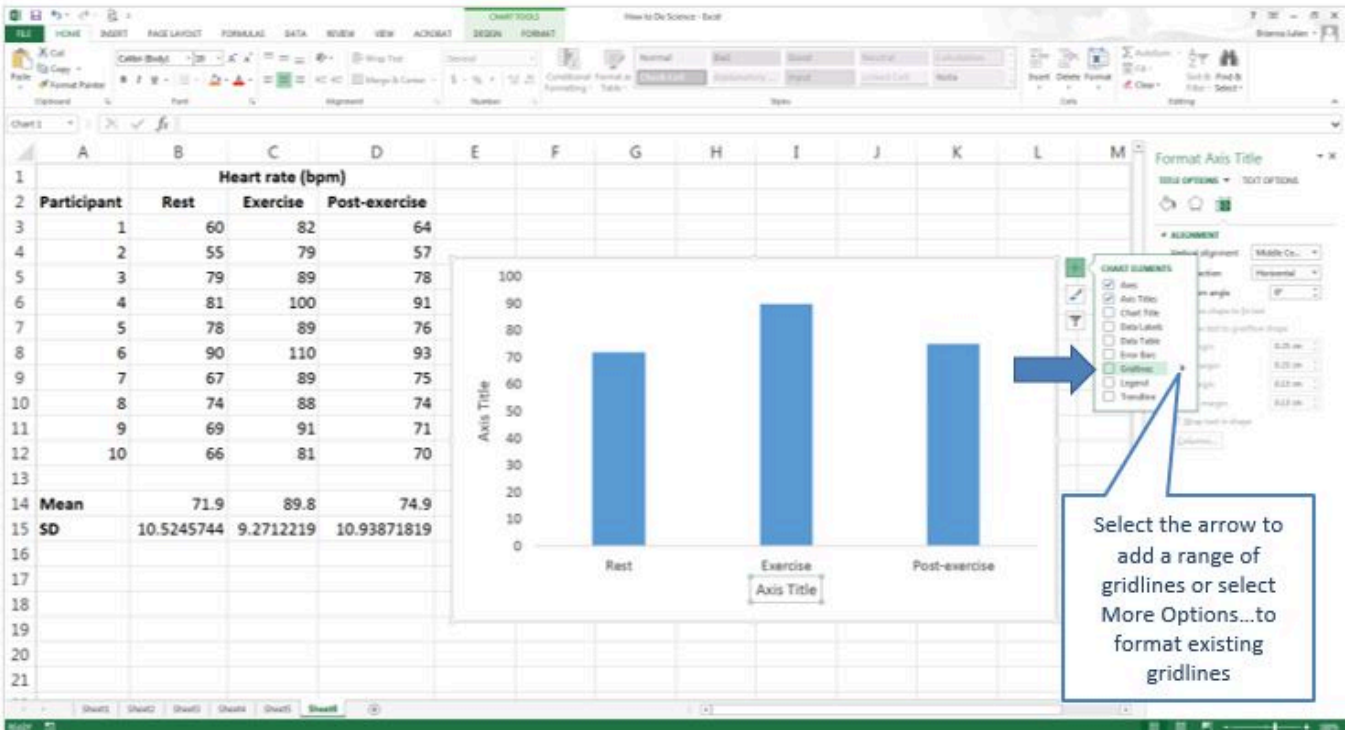



*Figure 4.6: Gridlines. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Adding error bars

Check the box next to **'Error Bars',** click on the arrow and select **'More Options'.**

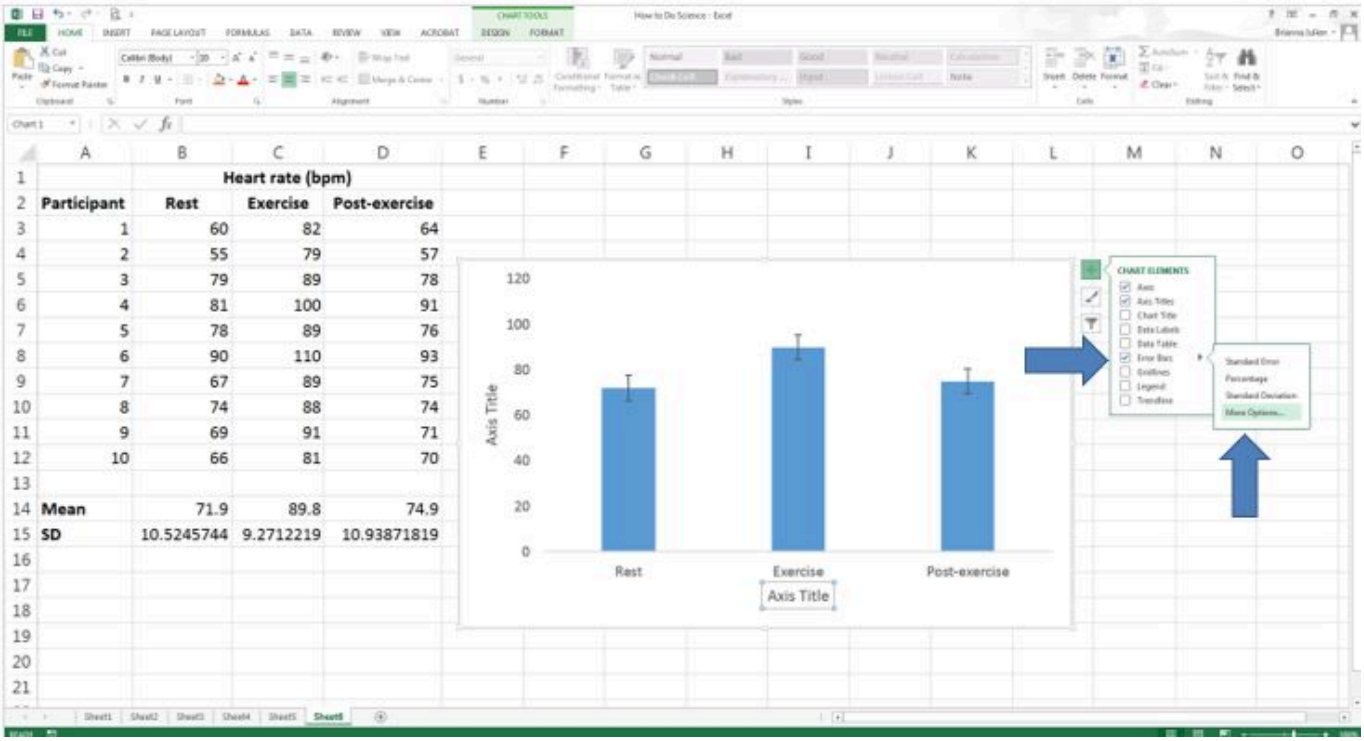



*Figure 4.7: Error bars. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

You will now have access to the **'Error Bars'** formatting tab on the right-hand side of the screen. For **'Error Amount',** select the '**Custom'** option and click the **'Specify Value'** button.

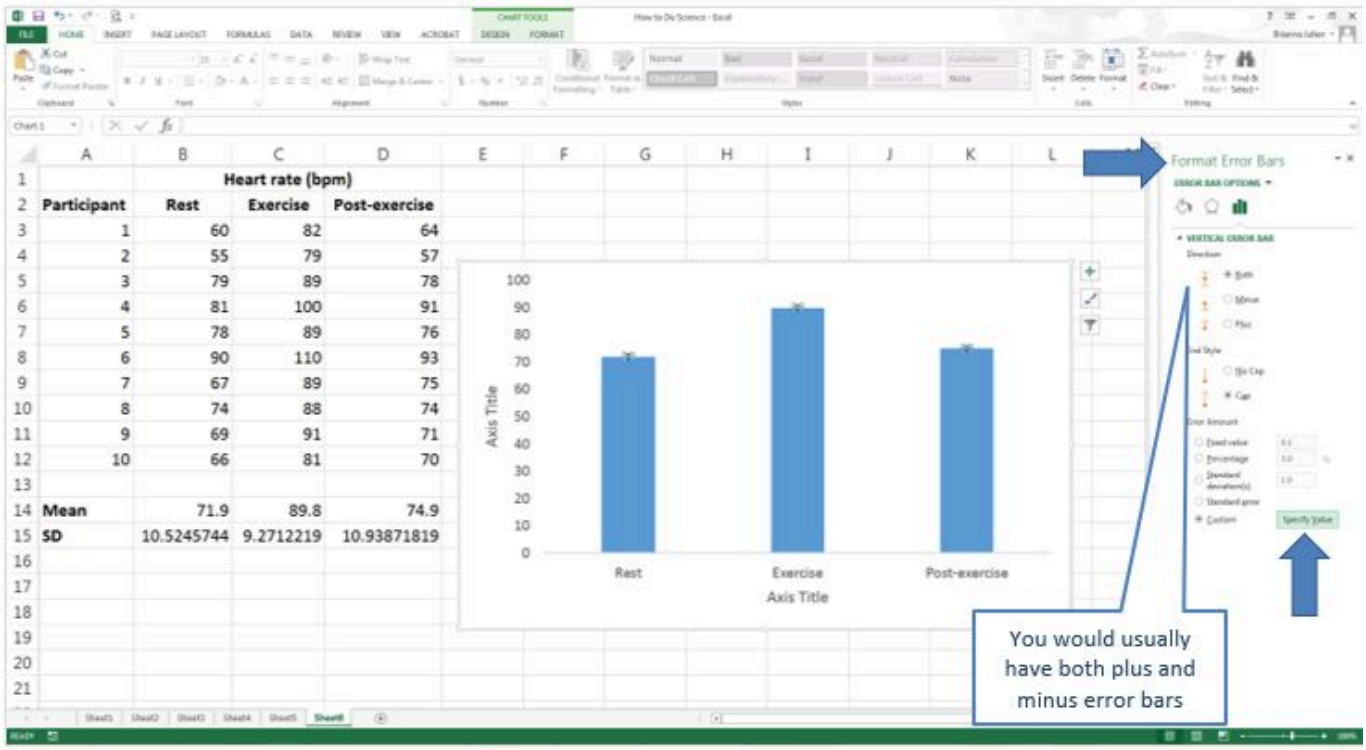



*Figure 4.8: Error bar formatting tab.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

The **'Custom Error Bars'** dialogue box will appear. This is where you add the cell references for the values to be used for the error bars. When adding both positive and negative error bars, you enter the same cell locations/ error bar values to both boxes (cells B15:D15 in this example).

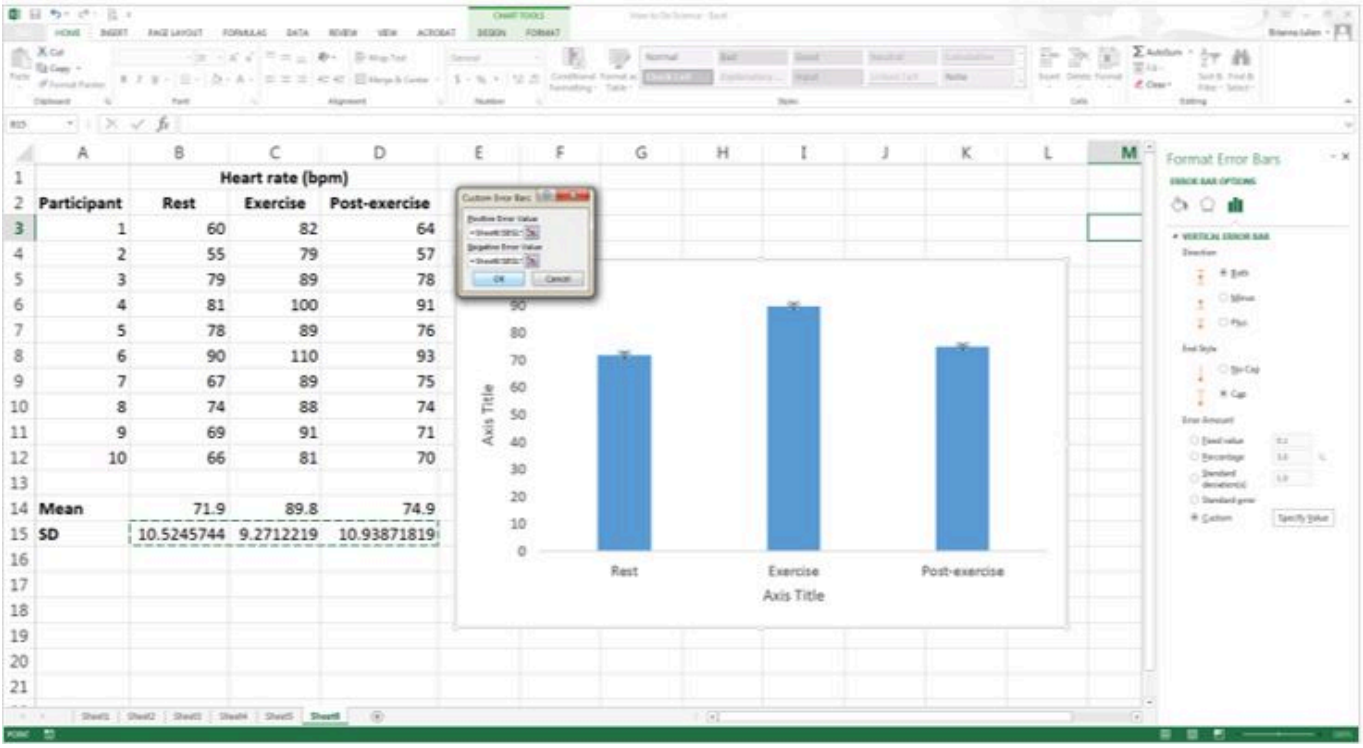



*Figure 4.9: Custom error bars dialogue box.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

If you get an error message after entering your standard deviation values into the **'Custom Error Bars'** boxes, check to make sure the text present in these boxes when the window first appeared was deleted completely before you added your values.

Error bars (representing standard deviation) will appear on your graph.

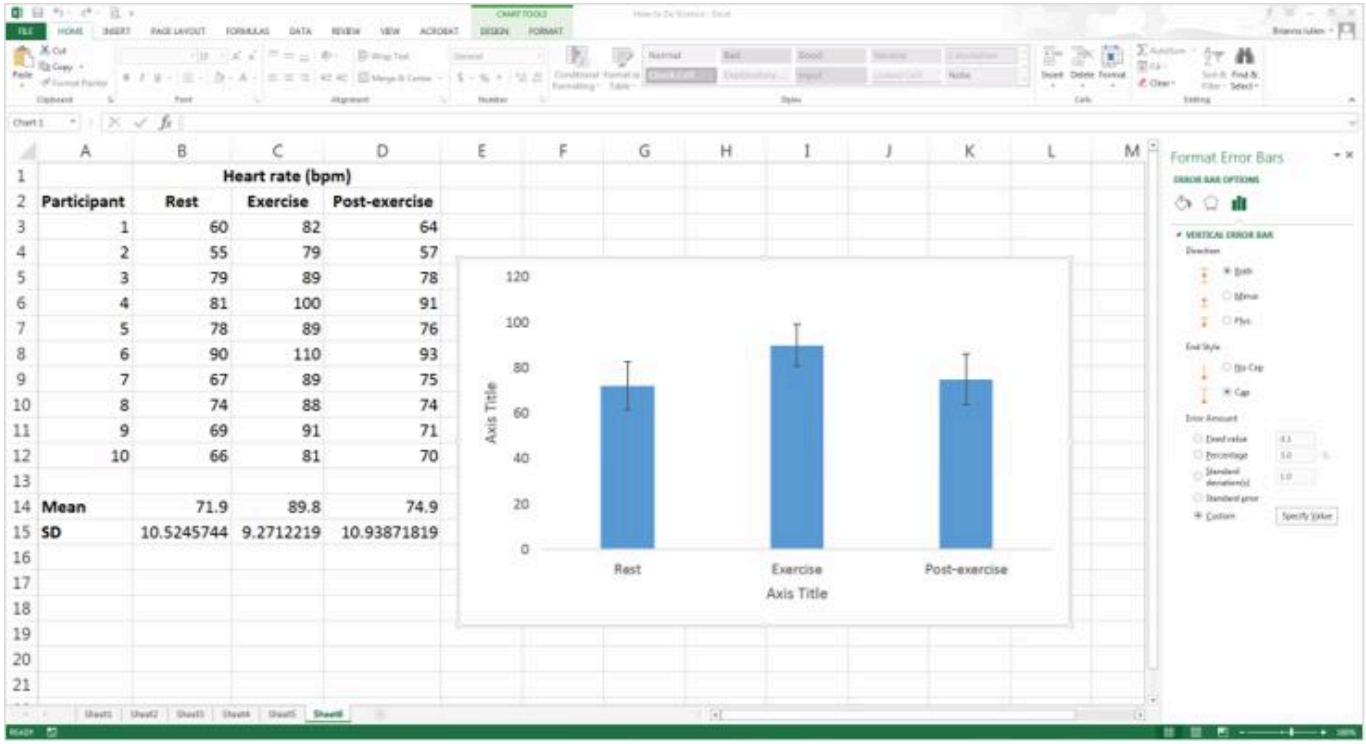



*Figure 4.10: Format error bars.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Adding significance symbols

Use the arrows below to learn how to add significant symbols in Excel.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=161#h5p-20

## Changing the look of your column graph using 'Format Data Series'

There are several things you can do to make your graph look more attractive. To access these options in Excel, you need to access the **'Format Data Series'** tab.

Use the arrows below to learn how to change the look of your column graph.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=161#h5p-21

## A completed scientific column graph

After following the previous instructions, you will have a completed scientific column graph. Add a figure legend (caption) below the graph and it will be ready to share. The example shown below is for illustration purposes only – usually data this simple would be presented in text with no need for a figure.

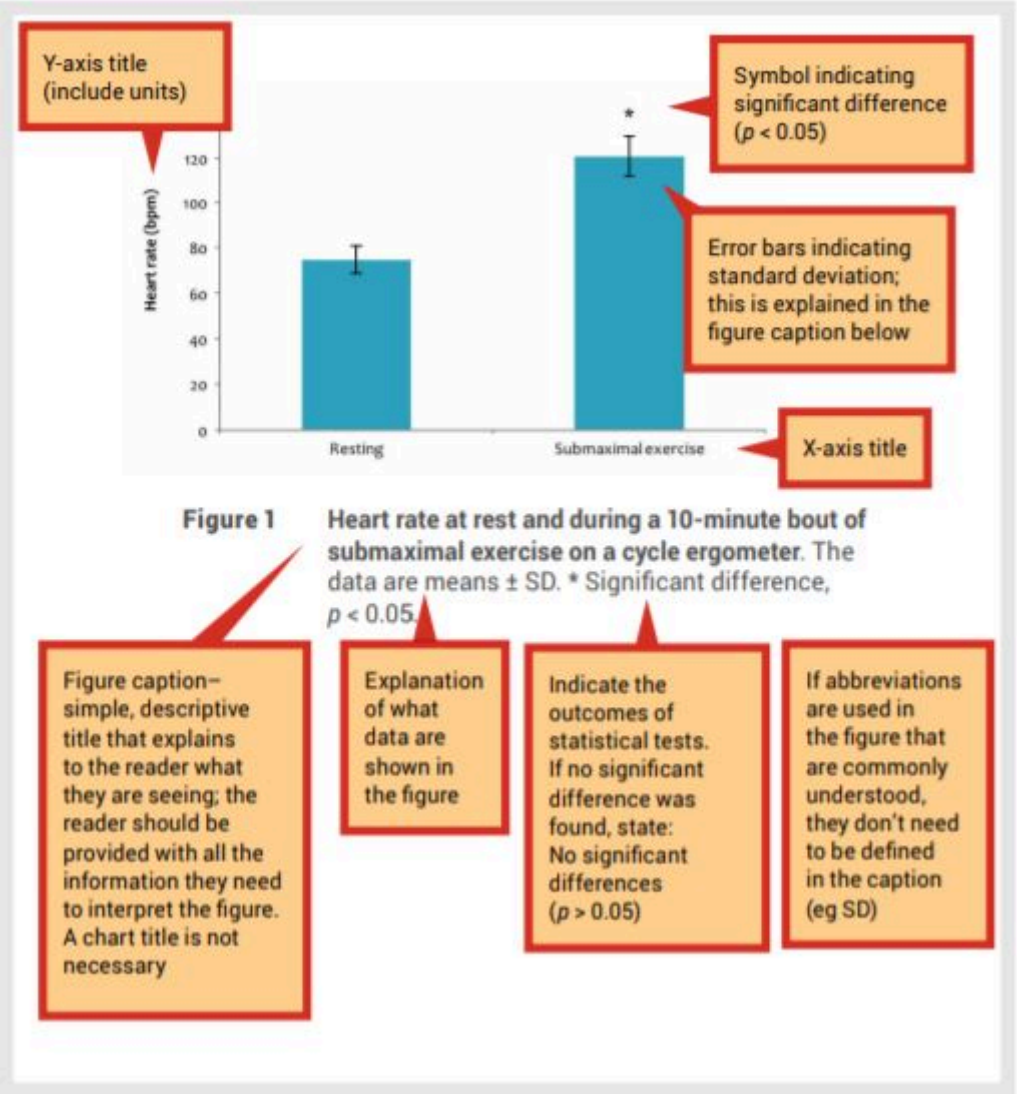



*Figure 4.11: A completed scientific graph.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## 4.2 CREATING A LINE GRAPH IN EXCEL

> Line graphs are used to show patterns and relationships across and between datasets when the general pattern is more important than the exact data values. Line graphs are particularly useful if you want to show a trend over time occurring in two or more groups.

Most of the principles of creating a line graph are the same as for creating a bar or column graph, so follow the instructions in **Section 4.1** when changing axis titles, adding error bars and significance symbols. Formatting specific for line graphs are described in the following steps.

Start by calculating descriptive statistics (mean, standard deviation) using one of the methods shown in **Chapter 3.**

1. Highlight the data you wish to graph.
2. Select the 'Insert' tab and choose the type of graph you want to create – for example, click the drop-down arrow next to the icon of a line graph and select a line graph style:

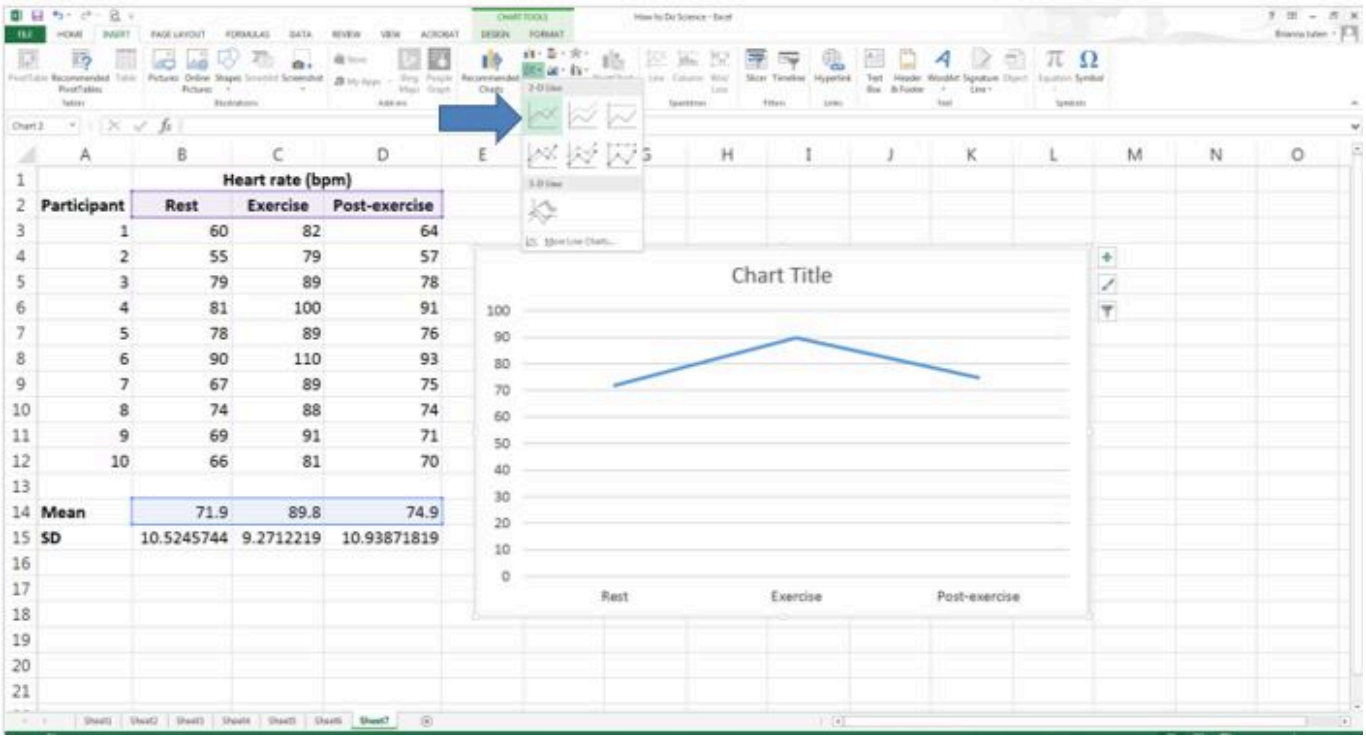



*Figure 4.12: Line graph in Excel.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

A simple line graph will appear in your spreadsheet and ready for you to format using the same steps shown in **Section 4.1.**

### Adding markers to data points

Select the data in your graph and the **'Format Data Series'** tab will appear on the right-hand side of your screen.

Click on the **'Line and Fill'** icon and then the **'Marker'** label and click the arrow at the side of **'Marker Options'.**

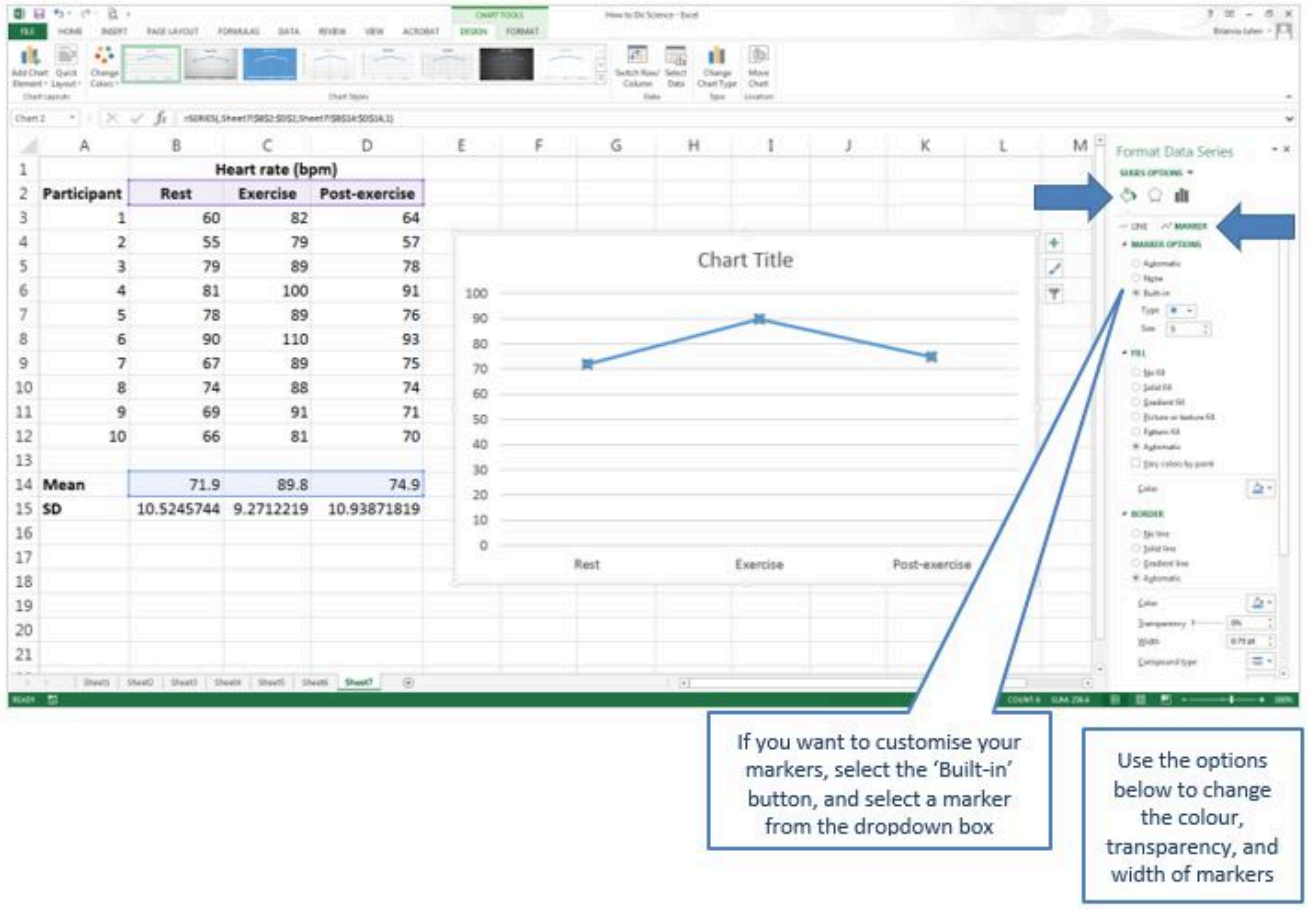



*Figure 4.13: Line graph options. **Source:** Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Choose an **'Automatic'** or **'Built-in'** marker. You will now have data markers on your line.

## A completed scientific line graph

After following the instructions above, you will have a completed scientific line graph. Add a figure name (caption) below the graph and it will be ready to share.

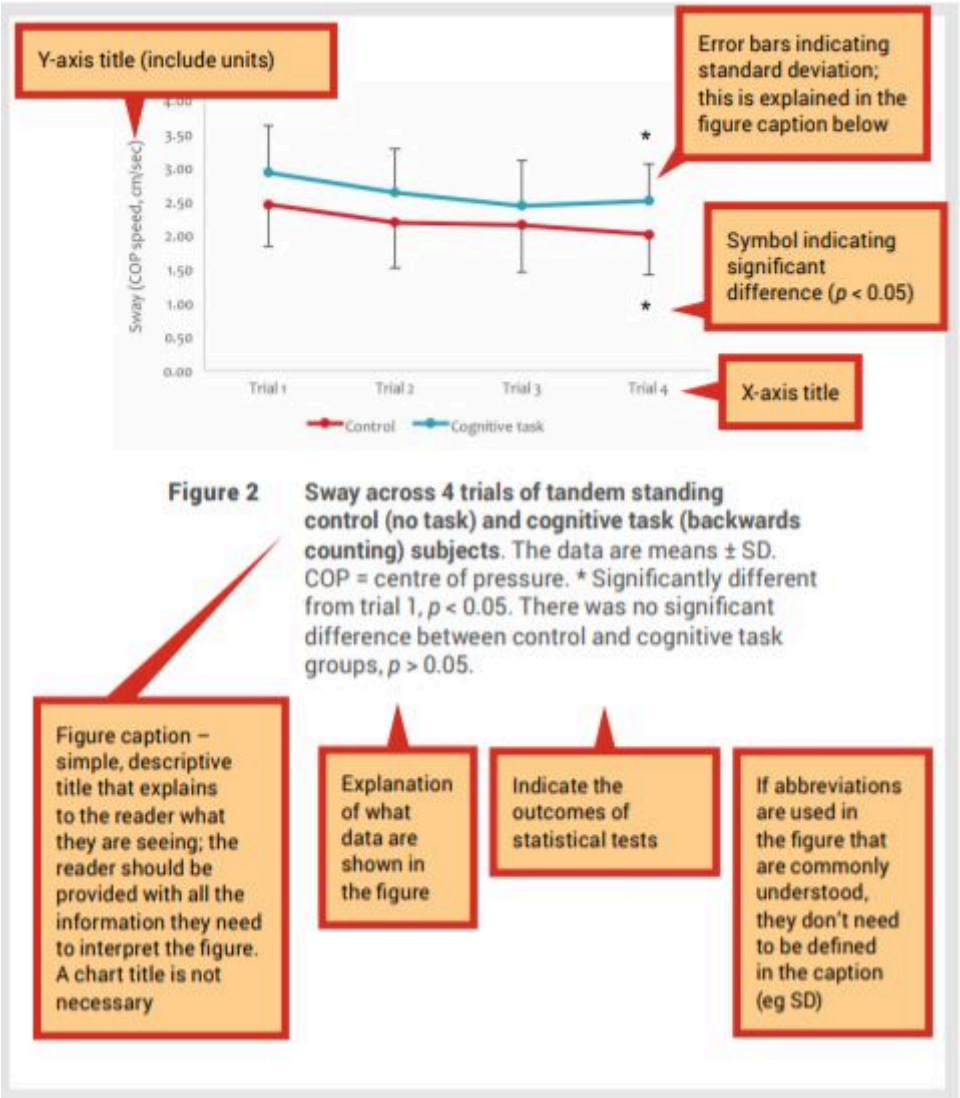



*Figure 4.14: A completed scientific line graph. **Source:** Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## 4.3 CREATING A TABLE USING WORD

> Tables are used to present many precise numerical values and other specific data in a small space and, importantly, when you don't want to show patterns and relationships across and between datasets.

Start by calculating descriptive statistics (mean, standard deviation) using one of the methods shown in **Chapter 3.** Note that the screenshots in this section are from Microsoft Office Professional Plus 2013; if you are using a different version, your screen may look slightly different.

### Entering a basic table

Use the arrows below to learn how to enter a basic table in Word.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=161#h5p-22

## A completed scientific table

After following the instructions above, you will have a completed scientific table. Add a table caption above the table and it will be ready to share.

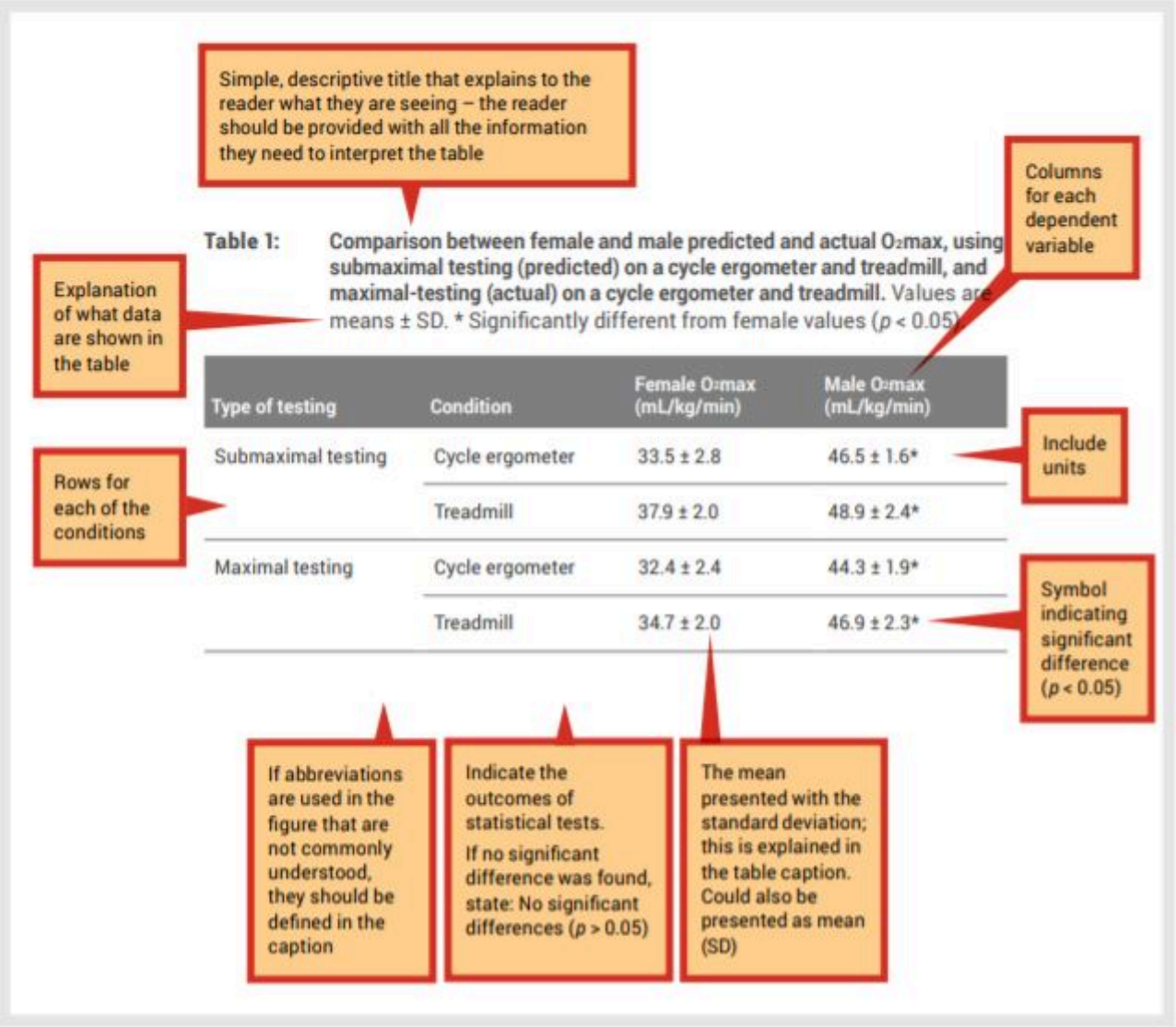



*Figure 4.15: Completed scientific table.* **Source:** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

Further reading

Speed, T 2014, *Statistics is More Than a Numbers Game – It Underpins All Sciences*, Office of the Chief Scientist, <www.chiefscientist.gov.au/2014/07/australia-2025-smart-science-statistics/>.

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=161#h5p-23

CHAPTER 5

# Accessing Scientific Literature and Referencing

An essential skill for all scientists to master is the ability to access relevant and reliable scientific information from a variety of sources.

You will need access to scientific literature for a variety of reasons:

- designing an experiment
- writing an article or essay
- designing a poster.

All of these tasks involved sourcing reliable, authoritative literature, and you'll need to know how to reference it.

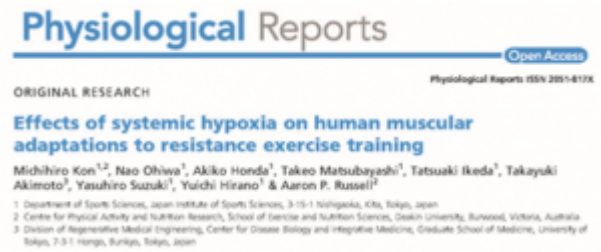
This chapter will provide student scientists with assistance in navigating the many avenues for locating scientific literature and referencing it, including using the reference management software EndNote.

## 5.1 TYPES OF SCIENTIFIC LITERATURE

The two main types of scientific literature are original investigations and literature reviews.

**Original investigations** (**Figure 5.1**) are published accounts of new studies undertaken on a particular topic. They will generally step the reader through the stages of the study:

- introduction
- methods
- results
- discussion
- conclusion
- references


Physiological Reports

Open Access

ORIGINAL RESEARCH

Effects of systemic hypoxia on human muscular adaptations to resistance exercise training

Michihiro Kon[1,2], Nao Ohiwa[1], Akiko Honda[1], Takeo Matsubayashi[1], Tatsuaki Ikeda[1], Takayuki Akimoto[3], Yasuhiro Suzuki[1], Yuichi Hirano[1] & Aaron P. Russell[2]

*Figure 5.1: An example of an original investigation. Source: Physiological Reports, used under CC BY 2.0*

Published **literature reviews** (**Figure 5.2**) present a synthesis and evaluation of the existing literature on a particular topic with the aim of gaining a new, deeper understanding of the topic. The review article will be structured around themes rather than stages of the scientific method.

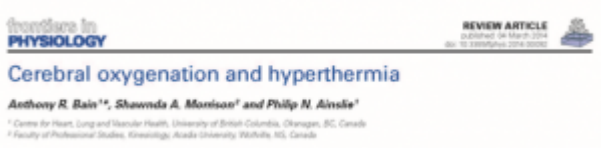



*Figure 5.2: An example of a literature review. Source: Frontiers in Physiology, used under CC BY 2.0*

## 5.2 ACCESSING SCIENTIFIC LITERATURE

You can locate scientific literature via Google Scholar, online databases such as PubMed, and the University of Southern Queensland library website when you are looking for a specific article or searching for literature on a specific topic.

### Google Scholar

Google Scholar provides a simple way to perform a broad search for scholarly literature. From one place, you can search across many disciplines and sources:

- articles
- theses
- books
- abstracts
- court opinions.

Academic publishers, professional societies, online repositories, universities and other web sites all publish these types of literature. Google Scholar helps you find relevant work across the world of scholarly research.

Box 5.1: Search tips

- Set your preferences to retrieve your university library resources: For example, select **Settings** > **Library Link** > **add University of Southern Queensland Library** > **Save**
- Use the asterisk * (e.g. child* will find child, children, childhood, childless)
- Use the asterisk as a placeholder to find a word within words e.g. “acquired * injury” finds acquired brain injury
- Use quotes to search by phrase (e.g. “type 2 diabetes” or “social media”)

Try this search in Google Scholar: “patient information” AND “back pain”
Extra help with using Google scholar is at this webpage.

### Databases, what are they and how do I use them to find information?

Databases are another way to find quality academic and scholarly information. The USQ library subscribes to many databases that are relevant to your studies in human physiology, such as:

- PubMed
- Web of Science
- ClinicalKey

- ScienceDirect

> PubMed is a database that comprises of more than 26 million citations for biomedical literature from MEDLINE, life science journals and online books. Citations may include links to full-text content from PubMed Central and publisher websites.

### Journals

Journals contain scholarly articles written by experts in specific disciplines. This tutorial explains what scholarly journals are and how to access them from the USQ library.

## 5.3 DETERMINING IF AN ARTICLE IS SCHOLARLY OR PEER REVIEWED

> It can be hard to work out if a journal is scholarly or peer reviewed. There is a lot of information online that looks like proper science, but isn't! These tips can help you determine if you are accessing reliable information.

**If searching in a library database:**

- Check to see if there is a box on the database search page that allows you to limit your search results to refereed or peer-reviewed journal articles.

**If you already have a journal article or title, use these option to check if it is scholarly or peer reviewed:**

- Look at the article itself for a header or similar that indicates refereed or reviewed.
- Look at the table of contents of the journal. Often items are grouped under a heading like 'reviewed articles'.
- Check the journal's website to see if a statement is made about the content being peer reviewed or refereed. However, be aware that not all the contents of a refereed journal will be refereed (e.g. books reviews, practice, commentaries, editorials are not peer reviewed).
- Look for the **Ulrichsweb** database in your library catalogue. If you have access, use the **'Quick Search'** drop down and select **'Title (keyword)'** and type in the journal title. Next to journal titles that include at least some refereed content is the image of a black and white striped 'referee's shirt'. You can also click on the journal title and you will see **'Refereed – yes or no'.**

## 5.4 LIBRARY WEBSITE RESOURCES TO ASSIST WITH SEARCHING FOR AUTHORITATIVE INFORMATION

Your university library will provide tutorials and resources to help you search for authoritative information.

## 5.5 REFERENCING

Anyone who reads your work will need to know where you got your information from if you didn't generate it yourself (e.g. the results of your experiment). The reference section provides a list of the references that you cited in the body of your work, whether it be a literature review, original investigation research article or essay.

It is important to accurately cite references in research papers to acknowledge your sources and ensure credit is appropriately given to authors of work you have referred to. An accurate and comprehensive reference list also shows your readers that you are well-read in your topic area and are aware of the key papers that provide the context to your research.

It is important to keep track of your resources and to reference them consistently in the format required by

the publication in which your work will appear. Most scientists will use referencing software to store details of all of the journal articles (and other sources) they use while writing their review article. This software also automates the process of adding in-text references and creating a reference list.

> In-text citations indicate where (within your sentences) you have used the ideas of other scientists. The in-text citations will either be provided as a number, or as the name of the author and date of publication.
>
> A reference list is a list of all the sources that you have used as in-text references in your scientific paper that enables the reader of your work to locate and verify the sources you have use.

Here are two basic formats for a reference list:

- an alphabetical listing by first author's last name (author–date system)
- a numerical listing that reflects the order of the citations in the body of the paper (number format).

The format will depend on the journal of publication, as each journal has their own specific referencing format.

A bibliography tends to use the author–date format, as the works might not be cited in the text.

## Author–date system

Author-date reference styles indicate in-text citations by placing the author's surname and the date of publication in brackets, and the reference list is in alphabetical order by author's surname. Harvard and APA are examples of author date styles.

The associated images show a section of the discussion, and a section of the reference list of a research article (Bain et al., 2014) that has used an author-date system.

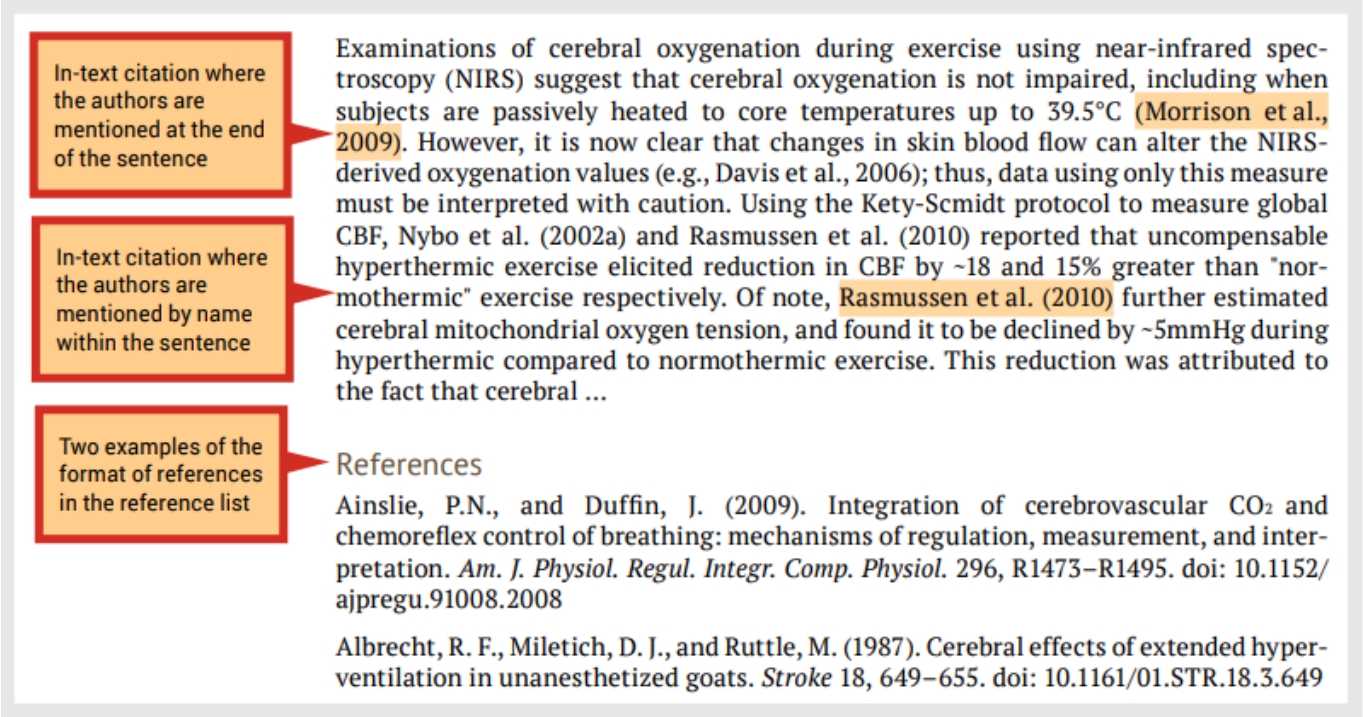



*Figure 5.3: An example of referencing using an author–date system. Adapted from Bain, AR, Morrison, SA & Ainslie, PN 2014, 'Cerebral oxygenation and hyperthermia', Frontiers in Physiology, vol. 5, p. 92. Used under a CC-BY 3.0 licence.*

Your university library will provide guidance and examples of the referencing styles you are expected to use. Ask your tutor which style you are to use for your assignment.

This short video shows you the basics of Harvard referencing. Please note there are different interpretations

of the style and use the resources provided by your university library when composing your own in-text citations and reference lists.

Click the drop down below to review the terms learned from this chapter.

**AN INTERACTIVE H5P ELEMENT HAS BEEN EXCLUDED FROM THIS VERSION OF THE TEXT. YOU CAN VIEW IT ONLINE HERE: HTTPS://USQ.PRESSBOOKS.PUB/HOWTODOSCIENCE/?P=207#H5P-24**

## REFERENCES

Bain, A.R., Morrison, S.A., & Ainslie, P.N. (2014). Cerebral oxygenation and hyperthermia. *Frontiers in Physiology, 5*, 92.

CHAPTER 6

# *Communicating Scientific Discoveries to Peers*

Science only moves forward when the findings of research investigations are communicated widely. After carrying out the experiment (an original investigation) and using the results to inform a conclusion as to the appropriateness of your hypothesis (**Chapter 2**), you are ready to share your findings (**Figure 6.1**).

Initially, research outcomes are communicated within the scientific community by scientists themselves. Results are then presented outside of the scientific community, by scientists or other professionals, such as science journalists and teachers.

Typically, scientists communicate their work within the scientific community by writing and publishing research articles and presenting posters and oral communications at scientific conferences. It is through these modes of communication that scientists have their work put through the gruelling test of peer review, where the work is both criticised and commended by other expert scientists. Only work that is recommended by peers will find its way to an issue of a peer-reviewed journal.

Peer-reviewed refers to the process by which scholarly work is checked by a group of experts in the same field to make sure it meets the journal standards before it is accepted or published.

The peer-review process for oral communications and poster presentations at scientific conferences is a little less gruelling than for journals, although, a peer-review process is still applied before the work is accepted by conference organisers. Although many scientists will grimace at the mention of 'peer-review', it is through this process that we increase the likelihood that valid science (and not pseudoscience) is shared with the world. Peer review is an essential part of the scientific process, to make important economic and health-related decisions that affect the future prosperity of humanity.

As with all forms of communication, scientific research articles, oral communications and poster presentations need to be prepared and delivered according to specific guidelines and using particular language. It is important that student scientists begin to understand these guidelines and are given opportunities to practise these forms of communication. This chapter provides a roadmap for preparing and delivering these important modes of scientific communication.


*Figure 6.1: The scientific method and the final stage – sharing results.* **Source:** *Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

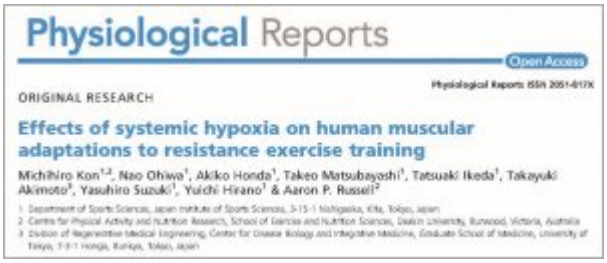
## 6.1 RESEARCH ARTICLES

A research article reports the results of original research, assesses its contribution to the body of knowledge in a given area, and is published in a peer-reviewed scholarly journal.

Research articles generally step the reader through the stages of the study. An example of a research article presenting the results of an original investigation is shown in below.

There are now 1000s of peer-reviewed journals in which scientists can publish the outcomes of their research. Each journal will have a slightly different format for their papers, but generally will include an abstract, introduction, methods, results, discussion and conclusion, and references section. In addition, some journals are requiring plain English summaries.

We will look at each section in turn and provide some tips for writing each section for your research.


Physiological Reports

Open Access

ORIGINAL RESEARCH

**Effects of systemic hypoxia on human muscular adaptations to resistance exercise training**

*Figure 6.2: Example of an original research article published in Physiological Reports.* **Source:** *Physiological Reports, used under a CC BY 2.0 licence.*

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=219#h5p-26

When looking at each section of a journal article, we will highlight how the authors have presented certain information processes. We will explain how to write the sections of an article by referring to a research article of an original investigation that was published in *Physiological Reports* and shown in **Figure 6.2.** Each section from the published paper is annotated to highlight important features of the format of the research article.

## Summary for non-experts

In recent years, it has become more common for journals to request authors to also provide a short summary of their research paper that is understandable by non-experts, such as members of the public, high school and university students, scientists from other disciplines, and members of the health care community. For example, *The Journal of Physiology* publishes a 'Key-points summary' at the beginning of each research article. According to the journal's editors, this summary was introduced with the following intentions:

- It can help readers to decide quickly if the paper is relevant or interesting.
- It helps scientists from disciplines related to physiology learn about the work by providing an easy-to-read summary of the research.
- It allows audiences other than scientists to engage with current research in physiology, including students, patients or carers, and the media.

The summaries are written clearly in plain English, without scientific jargon, abbreviations or acronyms. Sentences are kept as short as possible.

The specific format for a summary for the non-expert audience will vary from journal to journal but will have the same principles. We'll use the Key-points summary in *The Journal of Physiology* as an example to look at this type of writing in more detail.

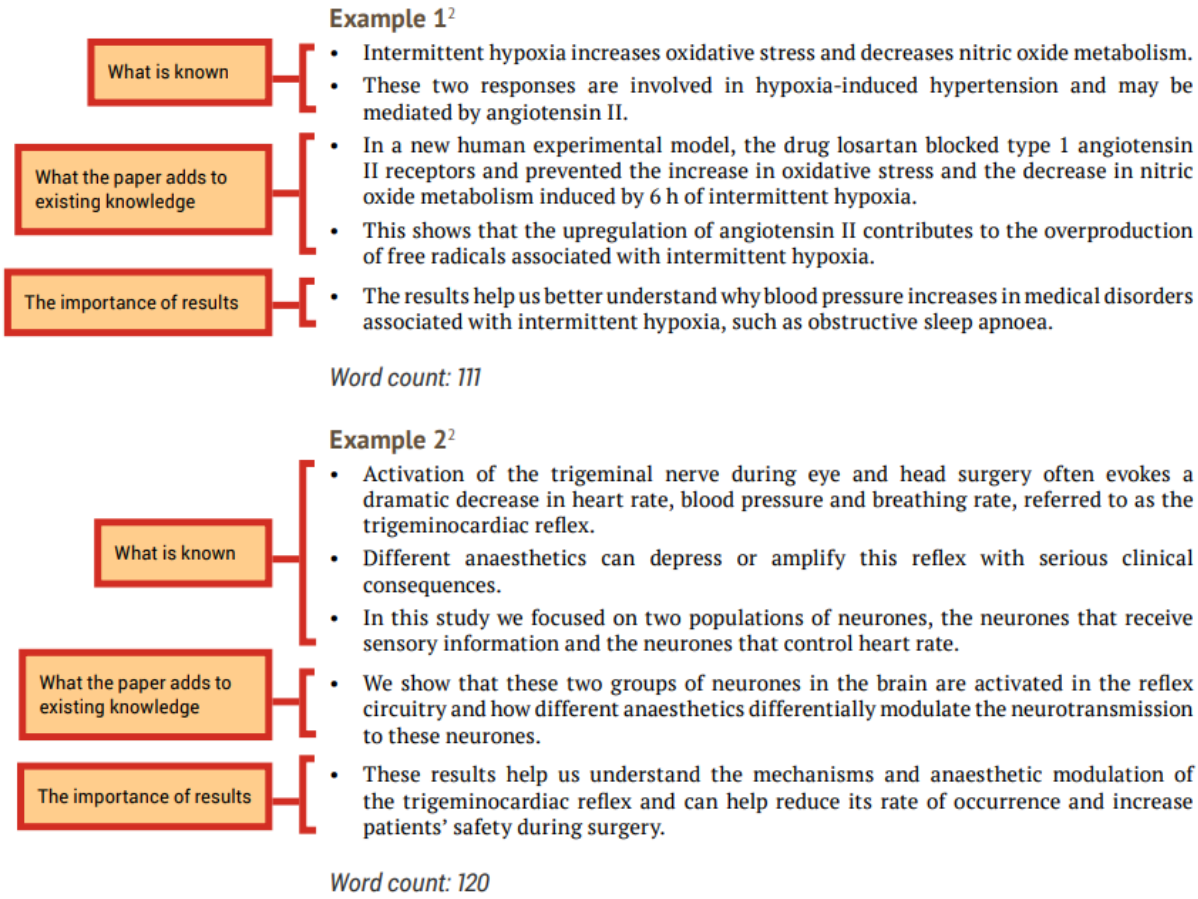
*The Journal of Physiology* gives authors guidelines for preparing their Key-points summary (The Physiological Society, 2016); these are summarised below along with an example that has been annotated to highlight important features.

General guidelines for writing a Key-points summary:

1. The summary should be written in no more than 150 words and no more than five bullet points
    1. One or two points on background to the present study
    2. One or two points on what the paper adds to existing knowledge
    3. One or two points on the importance of the results to body function in health and/or disease.
2. Language used should be understood by non-specialists with general scientific knowledge.
3. The summary should accurately reflect the findings of the paper and implications for future research.

Examples of Key-points summaries from *The Journal of Physiology* Instructions to Authors (The Physiological Society, 2016) have been highlighted to show how to write summaries that adhere to the guidelines and state:

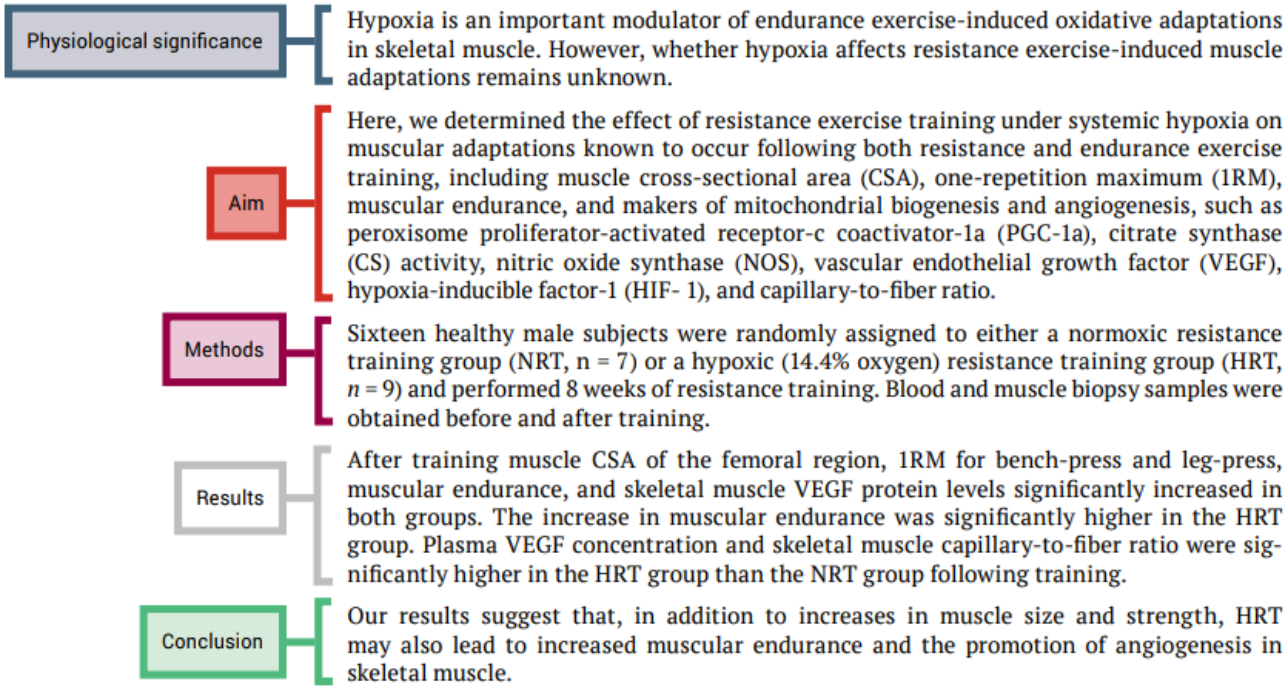
1. what is known
2. what the paper adds to existing knowledge
3. the importance of results




## Abstract

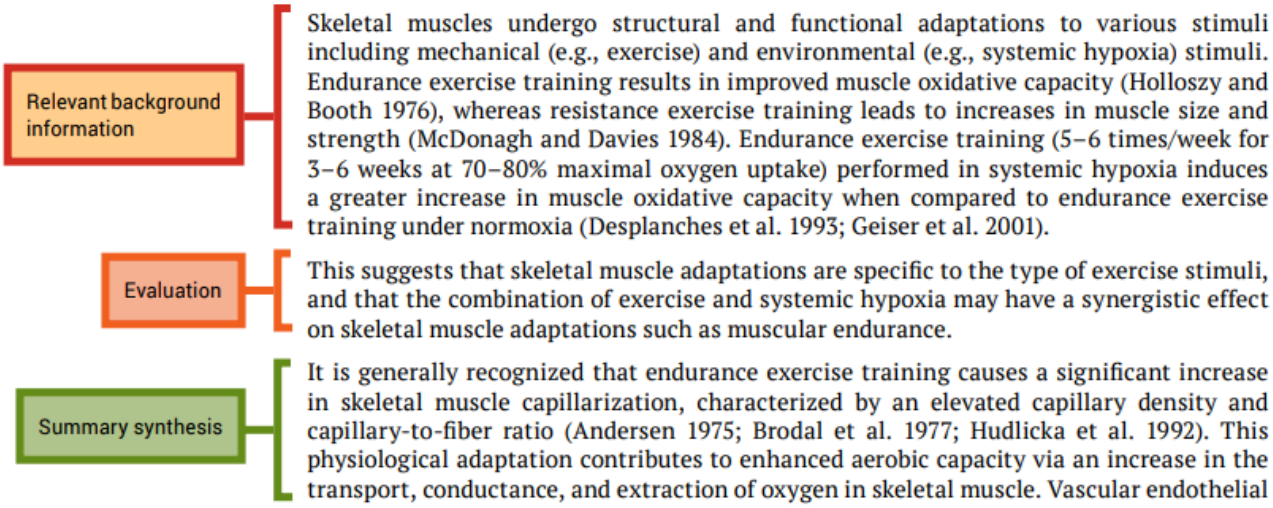
An abstract is generally a single paragraph that accurately reflects the contents of the paper – that is, the introduction, methods, results, and conclusion.

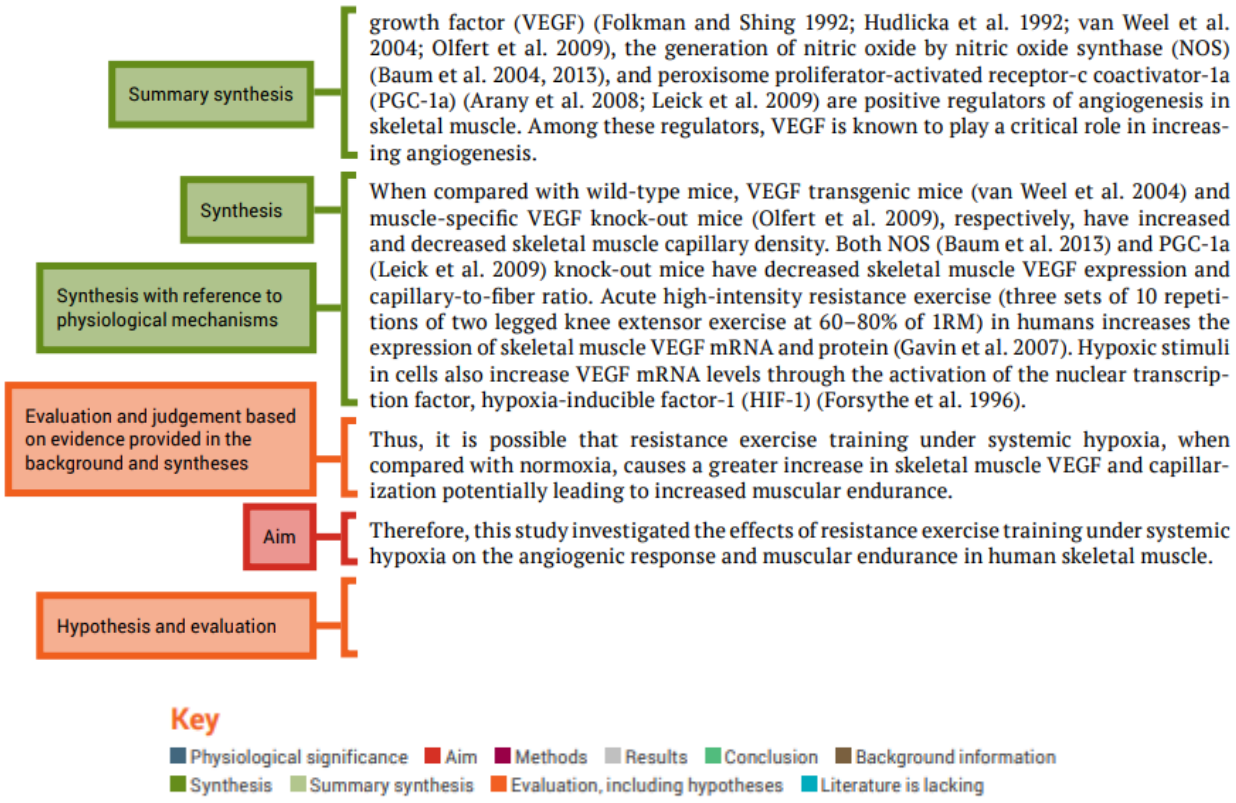
**Please note:** the examples below are adapted from Kon, M, Ohiwa, N, Honda, A, Matsubayashi, T, Ikeda, T, Akimoto, T, Suzuki, Y, Hirano, Y & Russell, A 2014, 'Effects of systemic hypoxia on human muscular adaptations to resistance exercise training', *Physiological Reports*, vol. 2, p. e12033. Used under a CC BY 2.0 licence.




## Introduction

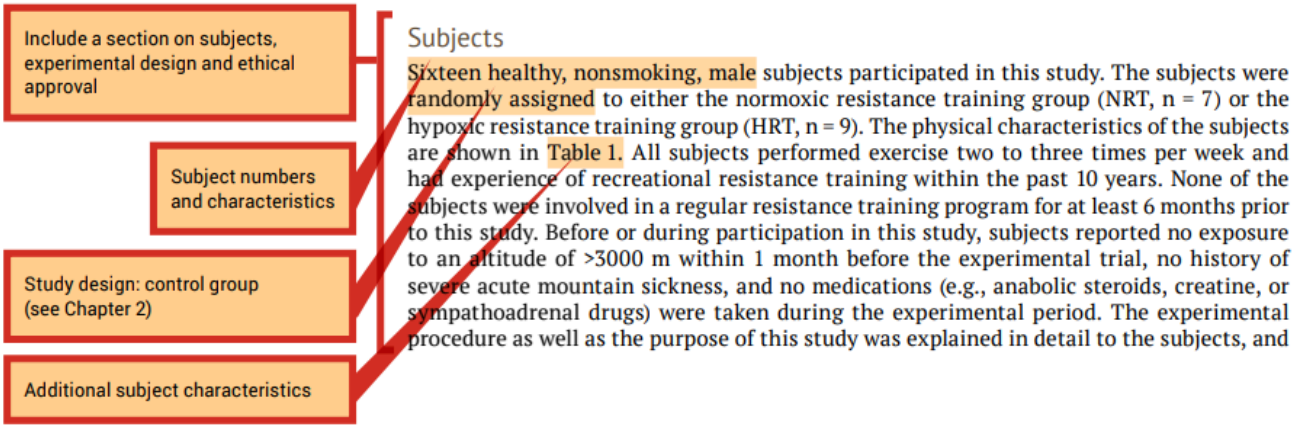
The introduction should establish the context and importance of the research. You may state your hypotheses and aims in the introduction; see **Chapter 2** for tips on writing these statements.

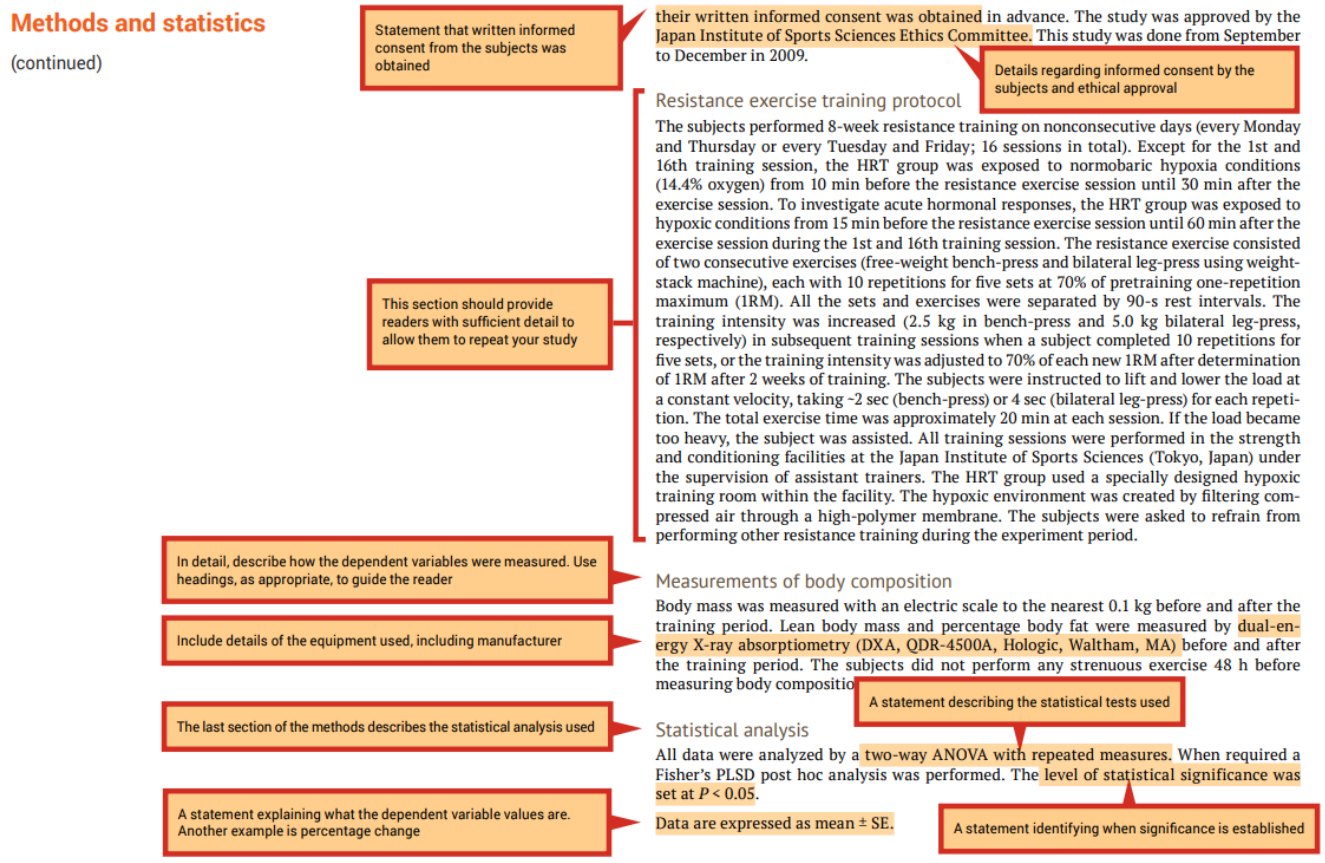





## Methods and statistics

In the Methods and statistics section, you explain clearly how you carried out your study. The importance of providing sufficient information in this section was discussed in **Chapter 1**.






## Results

Results appear in written form, supported by figures and tables, as appropriate. Examples of how to present all three forms of results are provided below. **Chapter 3** and **Chapter 4** provide details on conducting statistical tests, and creating figures and tables.

Reference to statistical significance is included in written text

Explanation of the results, in text form, which summarises the findings

## Body composition

In both the groups, body mass ($P < 0.05$) and lean body mass ($P < 0.01$) significantly increased, while percent body fat decreased after training (Table 1). There were no significant differences in these parameters between the two groups.

Refers to the relevant figures or tables

## Total training volume

Mean values plus or minus SD/SE appear in text. These data will not be repeated in a table or figure

Total training volume (calculated as load multiplied by repetitions) during the training period for the bench press was 36,500 ± 3933 kg for the NRT group and 42,000 ± 3304 kg for the HRT group, and for bilateral leg-press was 123,500 ± 10,795 kg for the NRT group and 129,111 ± 6006 kg for the HRT group (n.s. between groups).

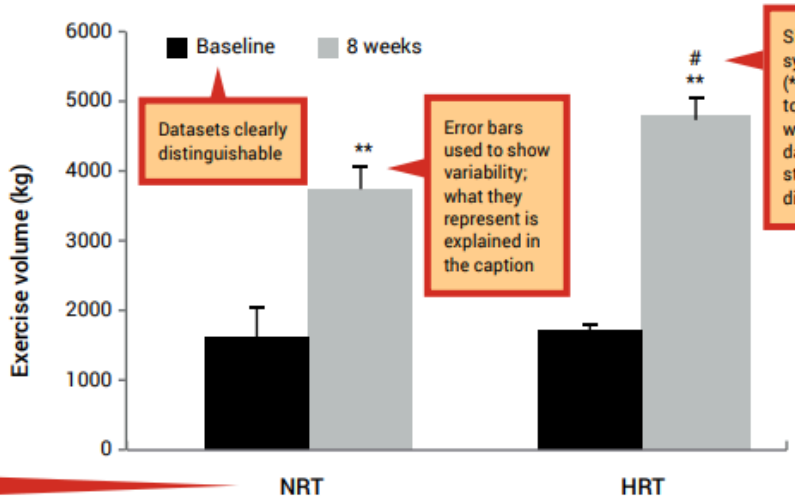



**Figure 2** Changes in exercise volume during leg-press exercises at 70% of 1RM before (baseline) and after (8 weeks) the resistance training program. NRT, nomoxic resistance training (n = 7); HRT, hypoxic resistance training (n = 9). Values are represented as means ± SE. Significantly different from baseline $^{**}P < 0.01$; significantly different from NRT $\#P < 0.05$.

Caption contains definitions of abbreviations used in the figure, which allows the figure to stand alone without reference to the text

Caption contains key for significance symbols used in figures

What data are presented

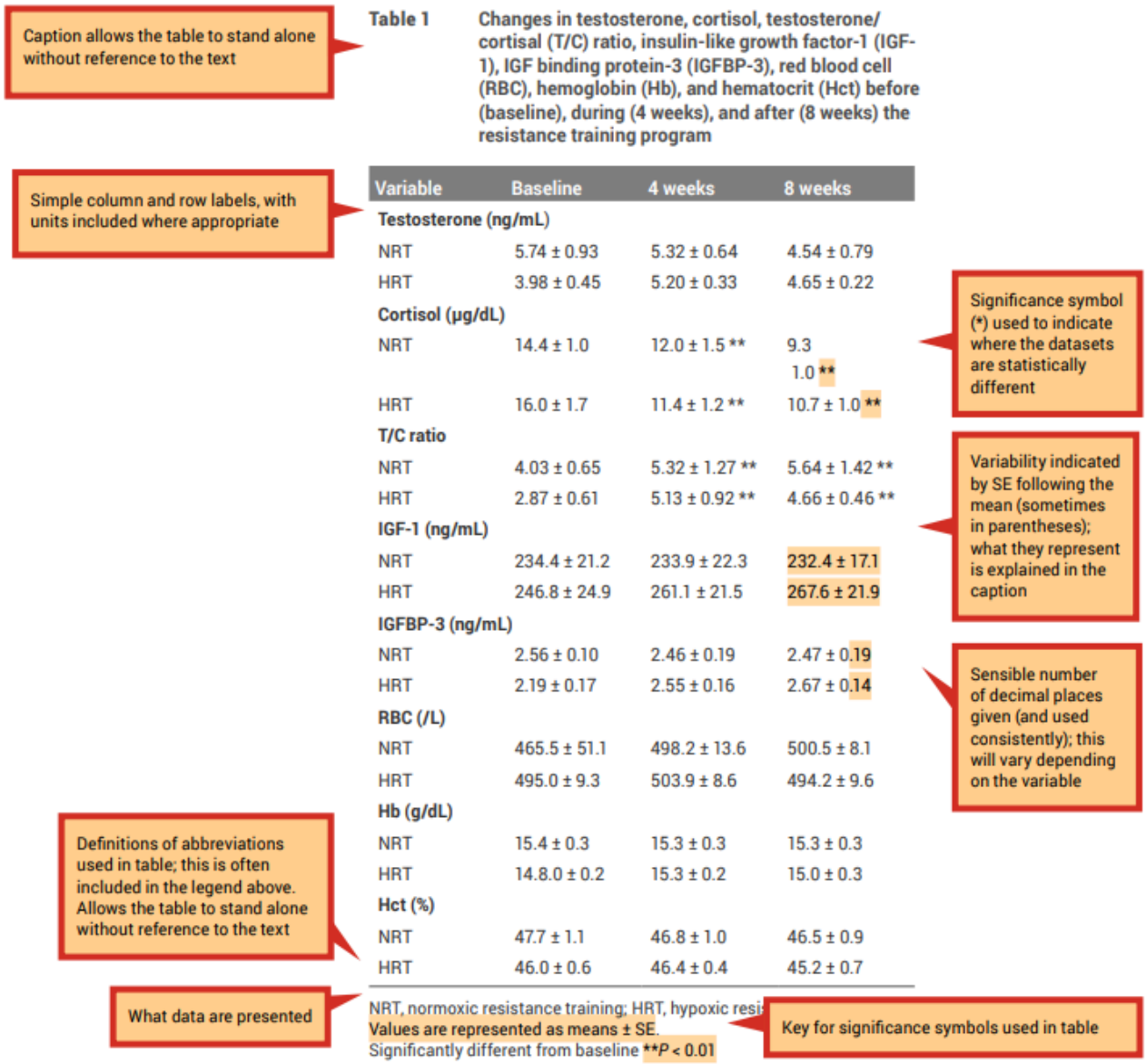



**Table 1** Changes in testosterone, cortisol, testosterone/cortisal (T/C) ratio, insulin-like growth factor-1 (IGF-1), IGF binding protein-3 (IGFBP-3), red blood cell (RBC), hemoglobin (Hb), and hematocrit (Hct) before (baseline), during (4 weeks), and after (8 weeks) the resistance training program

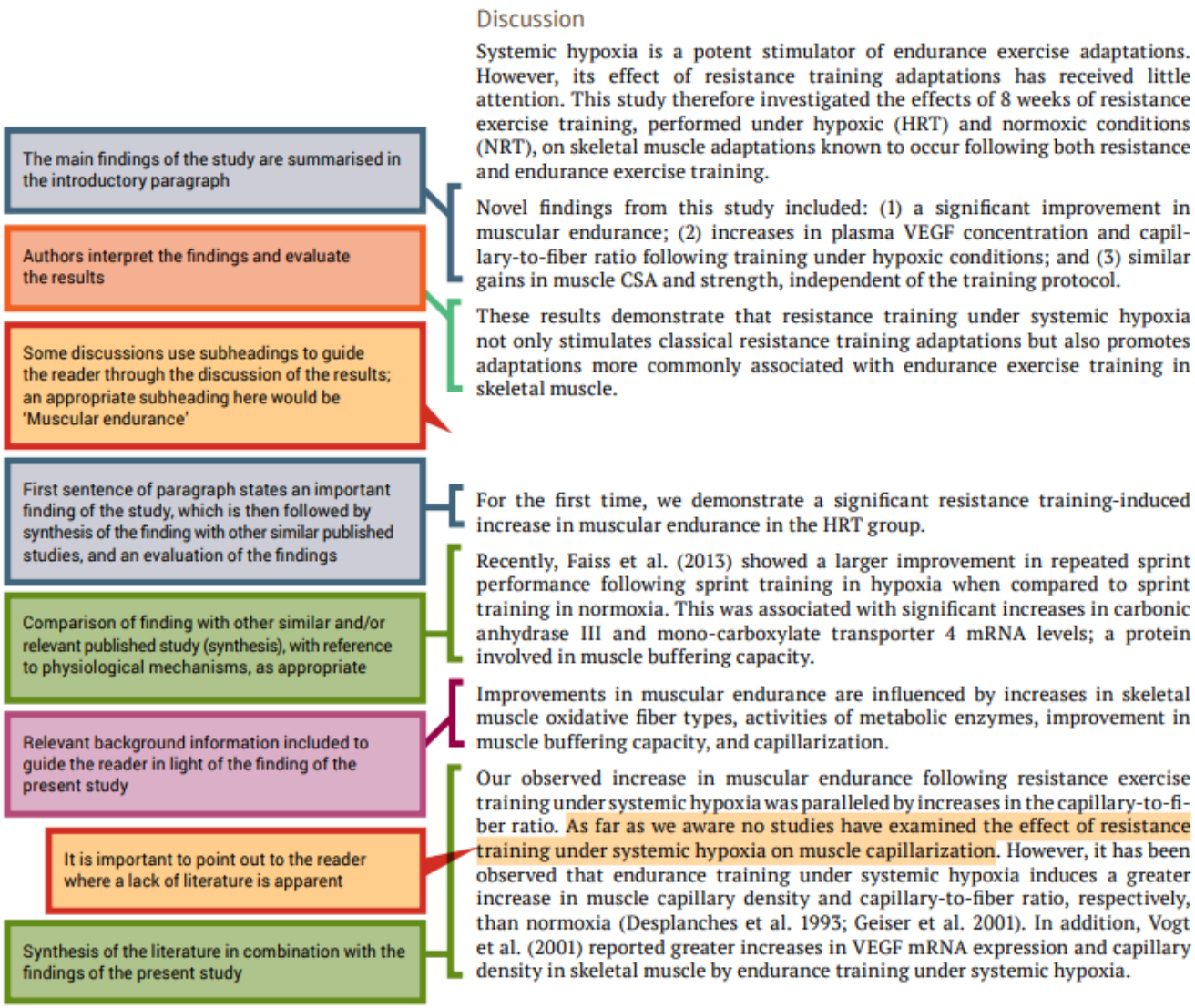
| Variable | Baseline | 4 weeks | 8 weeks |
|---|---|---|---|
| **Testosterone (ng/mL)** | | | |
| NRT | 5.74 ± 0.93 | 5.32 ± 0.64 | 4.54 ± 0.79 |
| HRT | 3.98 ± 0.45 | 5.20 ± 0.33 | 4.65 ± 0.22 |
| **Cortisol (µg/dL)** | | | |
| NRT | 14.4 ± 1.0 | 12.0 ± 1.5 ** | 9.3<br>1.0 ** |
| HRT | 16.0 ± 1.7 | 11.4 ± 1.2 ** | 10.7 ± 1.0 ** |
| **T/C ratio** | | | |
| NRT | 4.03 ± 0.65 | 5.32 ± 1.27 ** | 5.64 ± 1.42 ** |
| HRT | 2.87 ± 0.61 | 5.13 ± 0.92 ** | 4.66 ± 0.46 ** |
| **IGF-1 (ng/mL)** | | | |
| NRT | 234.4 ± 21.2 | 233.9 ± 22.3 | 232.4 ± 17.1 |
| HRT | 246.8 ± 24.9 | 261.1 ± 21.5 | 267.6 ± 21.9 |
| **IGFBP-3 (ng/mL)** | | | |
| NRT | 2.56 ± 0.10 | 2.46 ± 0.19 | 2.47 ± 0.19 |
| HRT | 2.19 ± 0.17 | 2.55 ± 0.16 | 2.67 ± 0.14 |
| **RBC (/L)** | | | |
| NRT | 465.5 ± 51.1 | 498.2 ± 13.6 | 500.5 ± 8.1 |
| HRT | 495.0 ± 9.3 | 503.9 ± 8.6 | 494.2 ± 9.6 |
| **Hb (g/dL)** | | | |
| NRT | 15.4 ± 0.3 | 15.3 ± 0.3 | 15.3 ± 0.3 |
| HRT | 14.8.0 ± 0.2 | 15.3 ± 0.2 | 15.0 ± 0.3 |
| **Hct (%)** | | | |
| NRT | 47.7 ± 1.1 | 46.8 ± 1.0 | 46.5 ± 0.9 |
| HRT | 46.0 ± 0.6 | 46.4 ± 0.4 | 45.2 ± 0.7 |

NRT, normoxic resistance training; HRT, hypoxic resi
Values are represented as means ± SE.
Significantly different from baseline $^{**}P < 0.01$

## Discussion and conclusion

The function of the Discussion is to interpret your results in light of what was already know about the topic, and to explain our new understanding of the issue after taking your results into consideration.

The Discussion connects to the Introduction by way of the questions or hypotheses, and the literature that you cited. It does **not** simply repeat or rearrange the Introduction. Instead, it tells how your study has moved us forward from the place you left the reader at the end of the Introduction. See **Chapter 2** for tips on writing a conclusion.


The main findings of the study are summarised in the introductory paragraph
Authors interpret the findings and evaluate the results
Some discussions use subheadings to guide the reader through the discussion of the results; an appropriate subheading here would be 'Muscular endurance'
First sentence of paragraph states an important finding of the study, which is then followed by synthesis of the finding with other similar published studies, and an evaluation of the findings
Comparison of finding with other similar and/or relevant published study (synthesis), with reference to physiological mechanisms, as appropriate
Relevant background information included to guide the reader in light of the finding of the present study
It is important to point out to the reader where a lack of literature is apparent
Synthesis of the literature in combination with the findings of the present study
Discussion
Systemic hypoxia is a potent stimulator of endurance exercise adaptations. However, its effect of resistance training adaptations has received little attention. This study therefore investigated the effects of 8 weeks of resistance exercise training, performed under hypoxic (HRT) and normoxic conditions (NRT), on skeletal muscle adaptations known to occur following both resistance and endurance exercise training.
Novel findings from this study included: (1) a significant improvement in muscular endurance; (2) increases in plasma VEGF concentration and capillary-to-fiber ratio following training under hypoxic conditions; and (3) similar gains in muscle CSA and strength, independent of the training protocol.
These results demonstrate that resistance training under systemic hypoxia not only stimulates classical resistance training adaptations but also promotes adaptations more commonly associated with endurance exercise training in skeletal muscle.
For the first time, we demonstrate a significant resistance training-induced increase in muscular endurance in the HRT group.
Recently, Faiss et al. (2013) showed a larger improvement in repeated sprint performance following sprint training in hypoxia when compared to sprint training in normoxia. This was associated with significant increases in carbonic anhydrase III and mono-carboxylate transporter 4 mRNA levels; a protein involved in muscle buffering capacity.
Improvements in muscular endurance are influenced by increases in skeletal muscle oxidative fiber types, activities of metabolic enzymes, improvement in muscle buffering capacity, and capillarization.
Our observed increase in muscular endurance following resistance exercise training under systemic hypoxia was paralleled by increases in the capillary-to-fiber ratio. As far as we aware no studies have examined the effect of resistance training under systemic hypoxia on muscle capillarization. However, it has been observed that endurance training under systemic hypoxia induces a greater increase in muscle capillary density and capillary-to-fiber ratio, respectively, than normoxia (Desplanches et al. 1993; Geiser et al. 2001). In addition, Vogt et al. (2001) reported greater increases in VEGF mRNA expression and capillary density in skeletal muscle by endurance training under systemic hypoxia.

Evaluation or explanation of the findings with reference to evidence published in the literature

Some discussions use subheadings to guide the reader through the discussion of the results; an appropriate subheading here would be 'Basal VEGF protein levels'

First sentence of the paragraph states the next important finding of the study, which is then followed by synthesis of the finding with other similar published studies, and an evaluation of the findings

Synthesis of the literature in combination with the findings of the present study

Evaluation of the findings

Synthesis

Evaluation of the findings

Combined these observations demonstrate that exercise training under systemic hypoxia may increase skeletal muscle angiogenesis, independent of the training mode. The greater angiogenesis is likely to be achieved by hypoxic resistance training-induced increase in VEGF levels. We were not able to define whether the greater increase in muscular endurance in the HRT group was due to the promotion of angiogenesis in skeletal muscle and this should be the focus of future studies.

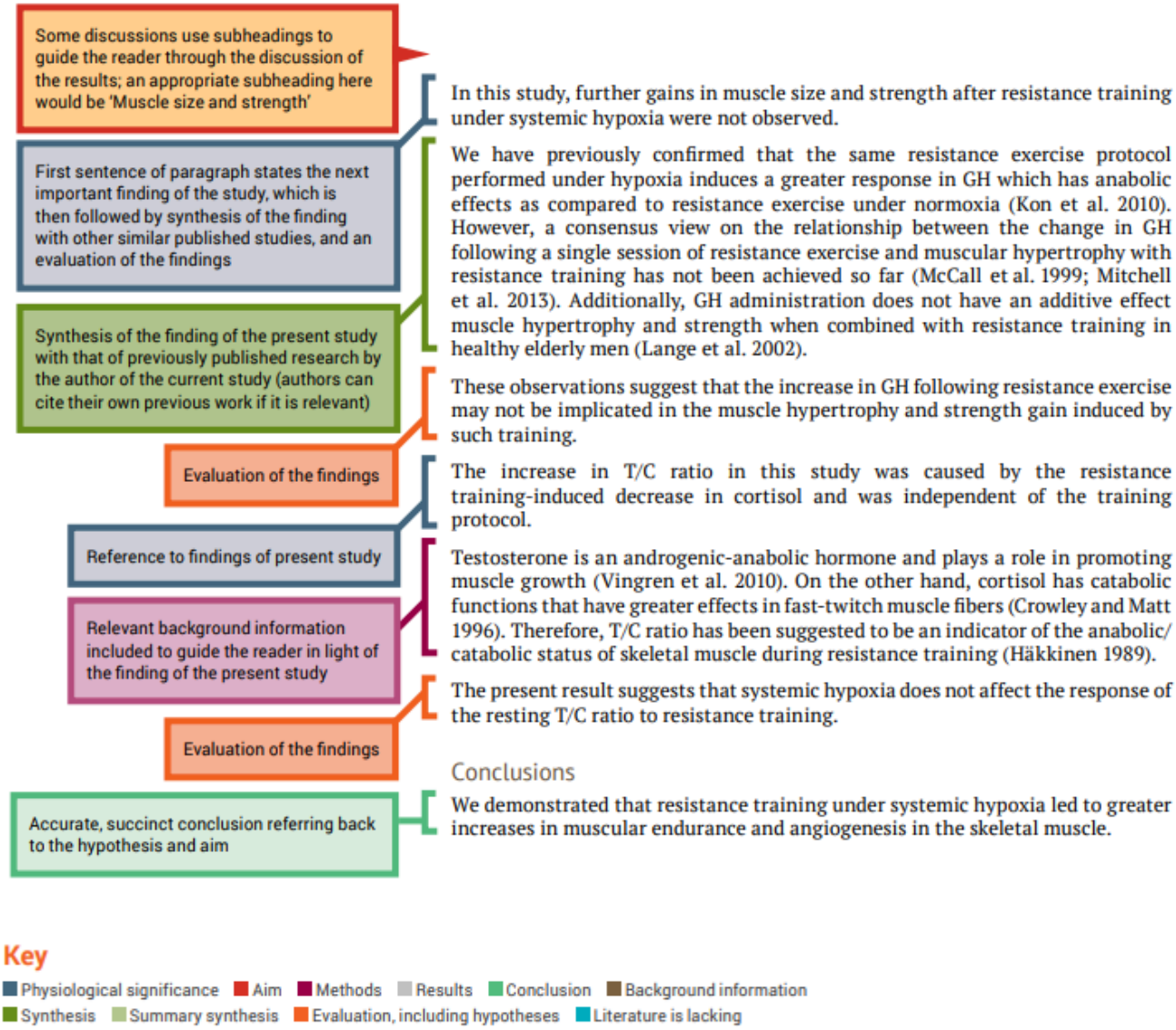
To our knowledge, this study is the first study to identify an increase in basal VEGF protein levels in skeletal muscle following resistance training.

Basal VEGF mRNA levels do not change following high-intensity resistance exercise training (Lundberg et al. 2013) or low-intensity resistance training under systemic hypoxia (Friedmann et al. 2003). In addition, the basal VEGF mRNA levels in skeletal muscle did not change after high-intensity intermittent training under systemic hypoxia. Following training in normoxia there are conflicting results with studies showing that VEGF mRNA levels may increase (Mounier et al. 2009) or decrease (Faiss et al. 2013). However, VEGF mRNA levels are increased between 2 and 4 h following moderate–high-intensity acute resistance exercise (Gavin et al. 2007) and 4 and 24 h following low-intensity acute resistance exercise performed with blood flow restriction-induced local hypoxia (Larkin et al. 2012).

The transient increase in VEGF mRNA following an acute resistance exercise bout may contribute to an increase in VEGF protein levels following repeated exercise bouts as observed in this study.

Some previous studies have obtained similar results regarding the changes of oxidative capacity to resistance training (MacDougall et al. 1979; Chilibeck et al. 1999; Masuda et al. 1999). Protein level of PGC-1a, a key regulator of mitochondrial biogenesis, angiogenesis, and endurance capacity, did not change, while CS enzyme activity, another regulator of endurance capacity, and mitochondrial content were reduced, following training

Resistance training might induce muscular hypertrophy to a greater extent than mitochondrial biogenesis, resulting in decreased CS activity relative to the muscle fiber area. It is possible that the increase in endurance capacity following HRT was not significantly influenced by changes in mitochondrial biogenesis or oxidative capacity.




## References

The reference section provides a list of the references that you cited in the body of your original investigation research article. The format will depend on the journal, as each journal has their own specific referencing format (see Chapter 5 for more about types of referencing formats).

It is important to accurately cite references in research papers to acknowledge your sources and ensure credit is appropriately given to authors of work you have referred to. An accurate and comprehensive reference list also shows your readers that you are well read in your topic area and are aware of the key papers that provide the context to your research.

In the research article by Kon et al. (2014) used as an example in this chapter, the reference list contains 34 items – imagine how much help referencing software would be. **Chapter 5** provides support for using EndNote, an example of reference management software.

# 6.2 POSTER PRESENTATION

> Scientific posters summarise research concisely and attractively to help publicise it and generate discussion when presented at scientific conferences.

Posters are presented at scientific conferences, and include brief text mixed with tables and/or graphs, and other presentation formats. A room will be setup with posters displayed on poster boards and times will be set aside for attendees to view the posters while their authors standby to answer questions and discuss their research.

The most important thing to remember when writing a poster is to keep things concise. A very wordy poster will be hard for a viewer to read, as the conference organisers will give you a maximum poster size you can display.

The hardest part about creating a poster is cutting out any information that is not strictly necessary; this takes time and possibly a number of drafts.

When creating a poster, you are stepping through a similar process to the process of writing up your research in research article format – however, with much less detail.

This section provides an example of a poster that presents an overview of an original investigation. We will also look at each section of the poster, and highlight important features of the format of the poster.

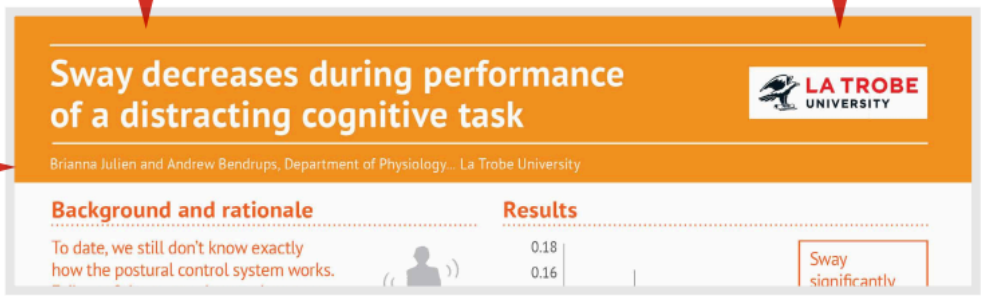
## Poster heading

The title, in large print across the top of the poster; this may be written in a way that summarises the findings of the study

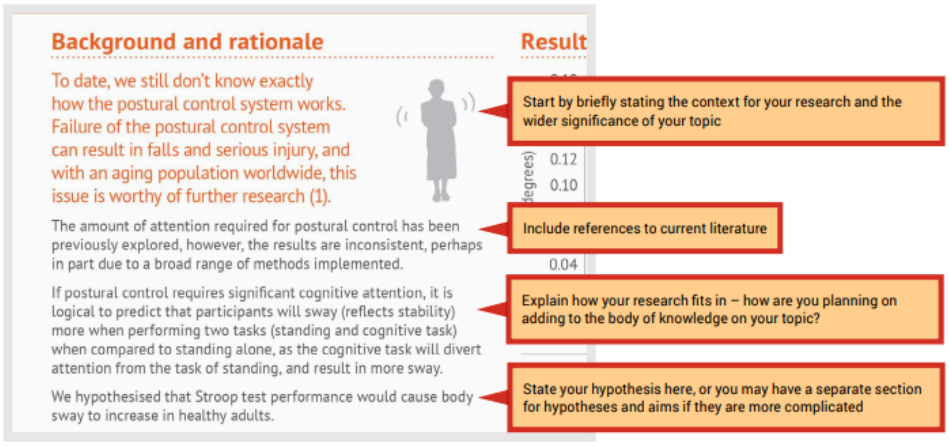
Include your institution's logo

Include full author details and details of where the research was conducted.

This may be more than 1 location if researchers from different places are collaborating




## Background or introduction



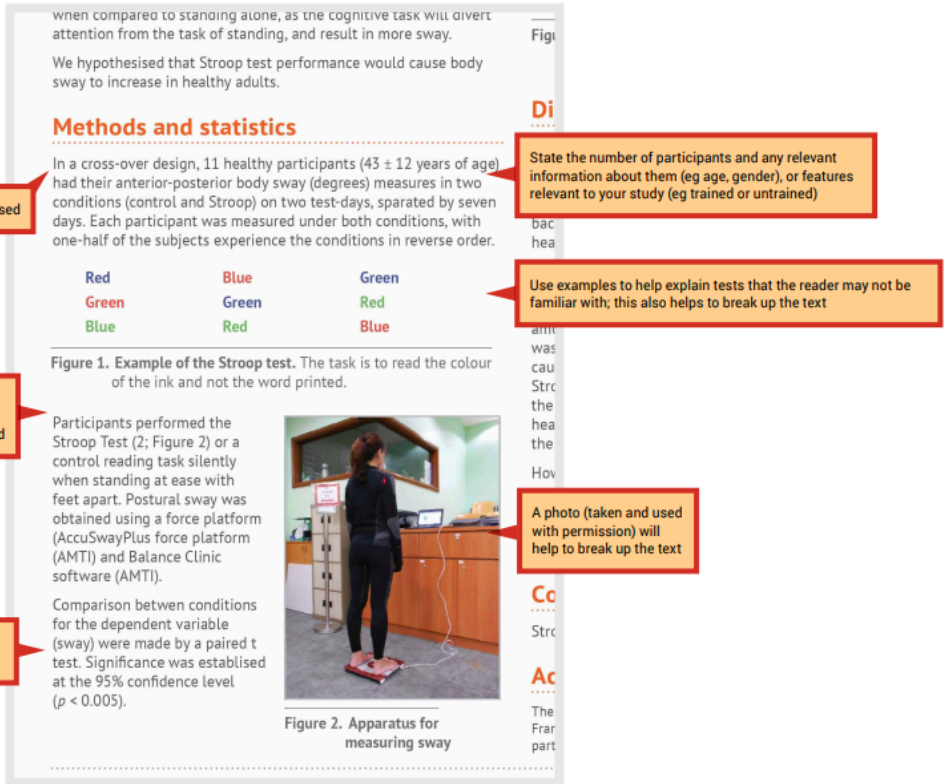

Start by briefly stating the context for your research and the wider significance of your topic

Include references to current literature

Explain how your research fits in – how are you planning on adding to the body of knowledge on your topic?

State your hypothesis here, or you may have a separate section for hypotheses and aims if they are more complicated

## Methods and statistics




Briefly explain the experimental design used

State the number of participants and any relevant information about them (eg age, gender), or features relevant to your study (eg trained or untrained)

Use examples to help explain tests that the reader may not be familiar with; this also helps to break up the text

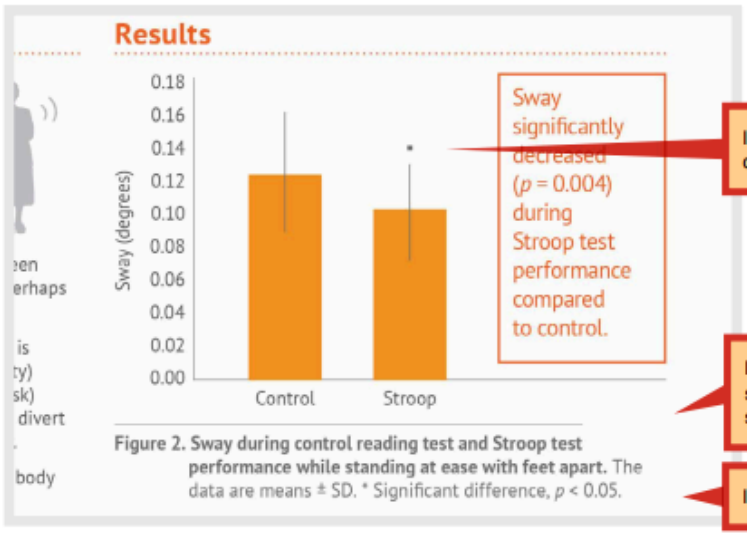
Explain what your participants did

A photo (taken and used with permission) will help to break up the text

Finish with details of data and statistical analysis

## Results

Remember to state your results only briefly the in text. Where appropriate, support this description with a figure or table.




Include significance symbols on figures where differences are significant

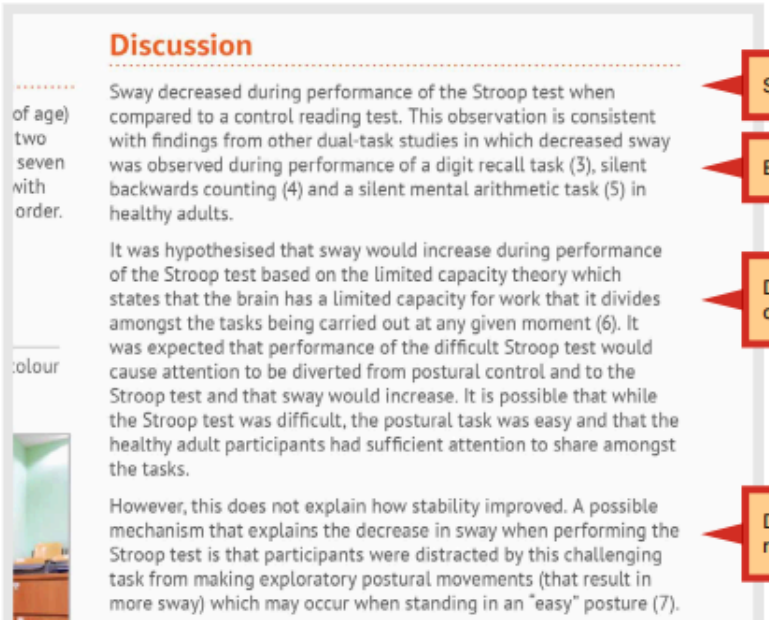
Include concise figure captions that state what the figure shows, what the data are, and what the outcome of the statistical analysis is

Include *p* values

## Discussion

Keep this short, but make sure you still explain the following points:

- How do your findings compare with what has been done previously in similar research?
- How do your results fit with your hypothesis – were your findings expected? Why or why not?
- What physiological mechanism do you propose to explain the findings?




Summarise your main findings

Explain how your findings compare with current literature

Discuss whether or not your findings were expected, and why or why not

Discuss the physiological mechanisms that may explain your results, with references

### Conclusion

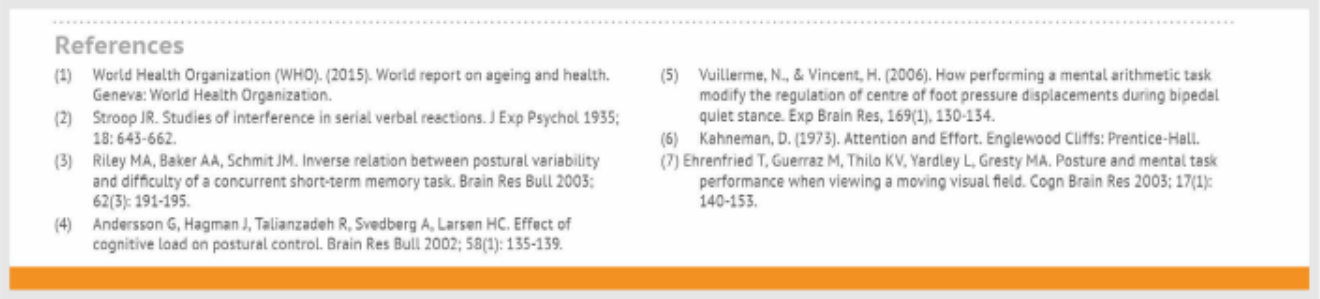
Keep the conclusion concise. We suggest using the schema introduced in **Chapter 2** to write a short, direct conclusion that is consistent with your hypotheses and aims


### Acknowledgments

The acknowledgements section is an optional chance to thank people who contributed to your poster, including during the planning, data collection, analysis and presentation phase.


### References

Keep your reference list as short as possible. Ensure your in-text citations are consistent with the reference list.




## 6.3 ORAL COMMUNICATION

A scientific oral communication is a prepared, purposeful presentation designed to share your research work with other scientists. Here, you try to convince your audience that your research is valid and important.

Oral communications are often given at scientific conferences and are usually followed by questions from fellow scientists in the audience (**Figure 6.3**).

Similar to a poster presentation, the challenge of an oral communication is keeping things concise. You will have a limited opportunity to present the outcomes of your original investigation, so you want to spend this time focused on the most important aspects of the project – particularly the results and the implications of these findings.

Video 6.1: How to prepare an oral research presentation [4 mins, 09 secs]

The Undergraduate Research Office at Michigan State University created this video called How To Prepare an Oral Research Presentation.
**Note:** Closed captions are available by selecting the CC button below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=219#oembed-1

> Most students will agree that oral communications are one of the most stressful tasks you will undertake during your degree. As a student scientist, you will have spent hours engaging with live and recorded lecture presentations and will have experienced many different types of presentations. As a result, you know what it is like to be an audience member. What kept you engaged? Consider the good and not so good lectures you have experienced as an audience member as you prepare your presentation. Try to embody the presenters that you enjoyed listening to.

When preparing your oral communication, you have three elements to consider:

- visual aids
- language use
- delivery.

## Visual aids

Very wordy presentation slides will be hard for the audience to read and will be overwhelming. You will need to cut out any information that is not strictly necessary; this takes time and possibly a number of drafts.

Remember, you don't need to include everything you are going to say on your slides. Rather, you should use the limited space on the slides to state key ideas and use these as prompts for your talk.

In a scientific oral communication, you should include slides for each of the major sections of a research article:

- introduction
- methods
- results
- discussio
- conclusion.

Given you have limited time, devote less time to your methods, and more to your results and discussion of the implications of your findings.

*Figure 6.3: Oral communication by Ashwin Baindur at the Bengali Wikipedia 10th Anniversary Celebration. Source: 'Ashwin Baindur – Presentation – Crafting Knowledgesmiths Attributes of Accomplished Wikipedia Editors- Bengali Wikipedia 10th Anniversary Celebration – Jadavpur University – Kolkata 2015-01-10 3317' by Biswarup Ganguly, used under CC BY 3.0 licence.*

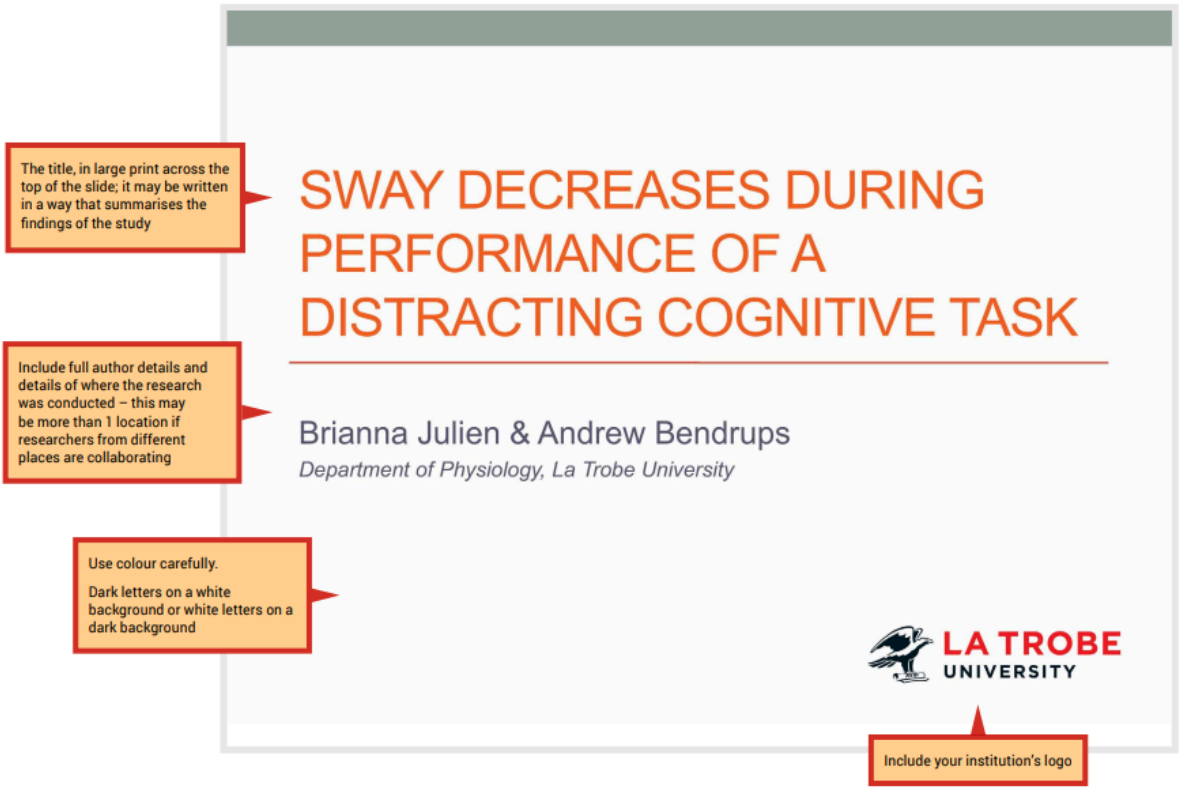
For your presentation slides, avoid large blocks of text. Try to break up the text you include using bullet points and also images where appropriate. Keep your presentation design simple – use dark fonts on a light background or light fonts on a dark background. Ensure that the font size is readable by your audience.

Avoid overly distracting slide transitions or sound effects; these detract from your talk and may appear unprofessional.

Take the time to proofread your slides so there are no spelling or grammatical errors.

The following sections show an example of slides from an overview of an original investigation. We discuss each section of the presentation and highlight important features relating to the content of the slides. We also provide suggestions for how slides can complement your talk.

**Title slide**



## Background and rationale

This could also be called Introduction. Use footnotes to reference other published work.

Start by briefly stating the context for your research and the wider significance of your topic

Explain how your research fits in – how are you planning on adding to the body of knowledge on your topic?

Include references to current literature

### Background & rationale

- We still don't know how the postural control system works
- Postural control system failure → falls and serious injury[1]
- Research on attention required for postural control has returned inconsistent results
- If postural control requires attention, we predict increased sway when performing two tasks compared to standing alone
  - Cognitive task will divert attention from the task of standing

Use images to break up the text

(1) World Health Organization (WHO). (2015). World report on ageing and health. Geneva: World Health Organization

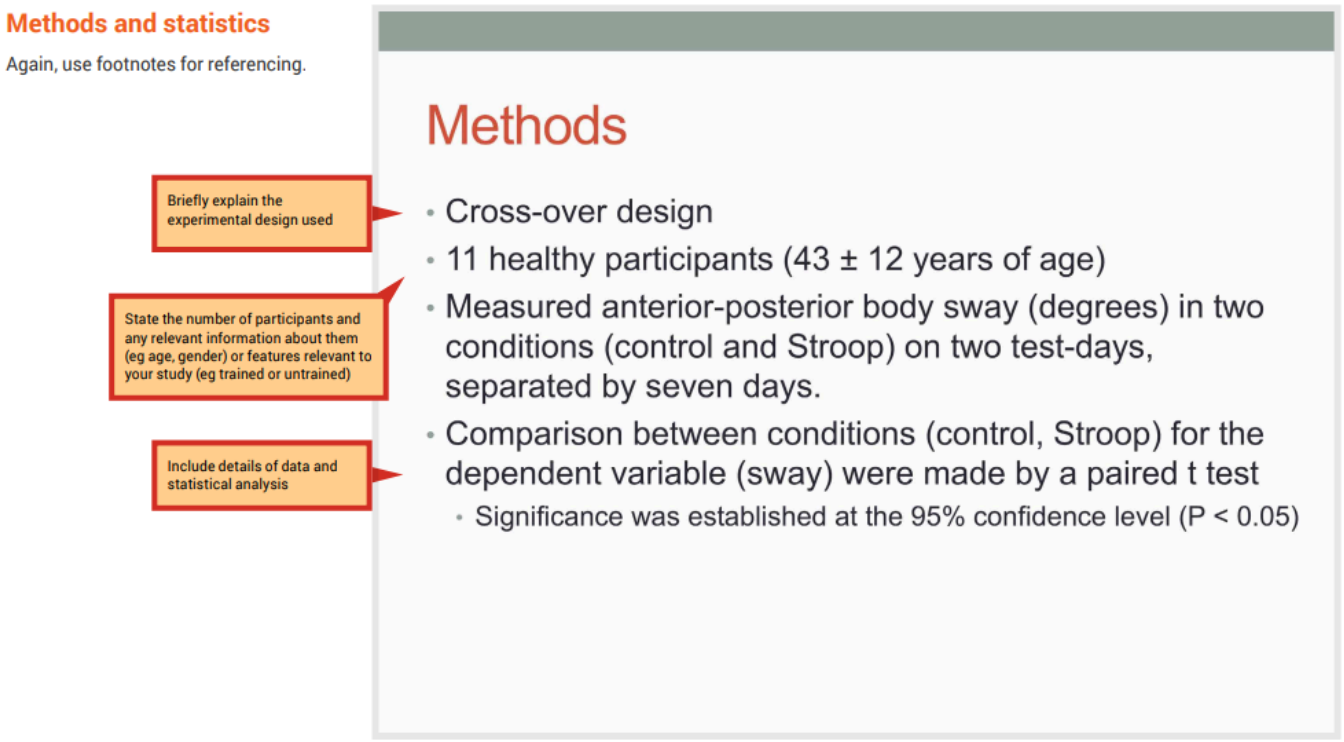
Source (image): 'Korea-Jeonju-Jultagi-02 cropped' by Rhett Sutphin, used under CC BY 2.0

## Hypothesis and aim

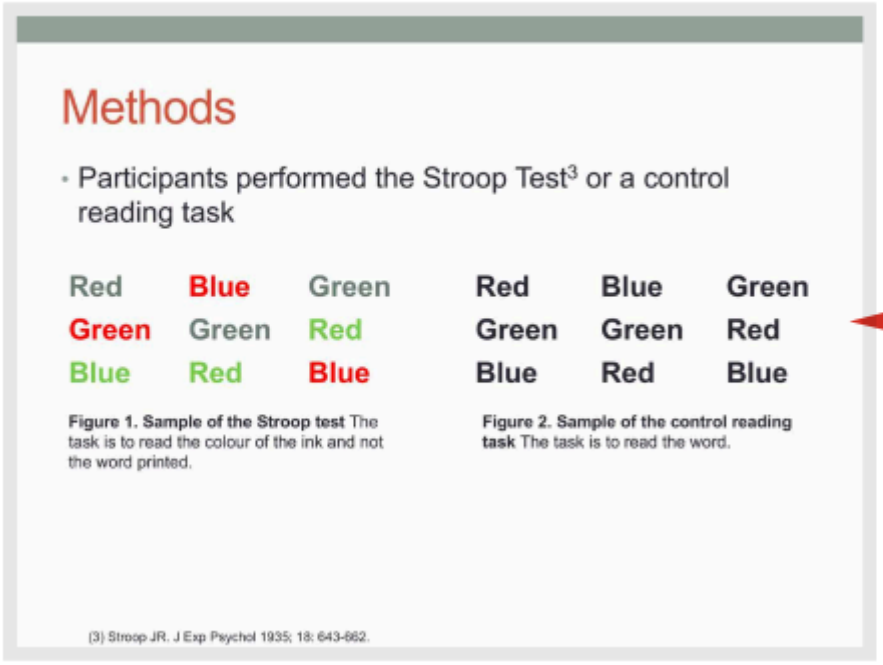
State your hypothesis and aim as part of the 'Background and rationale'. If they are complicated, you may have a separate section for hypotheses and aims

### Hypothesis & aim

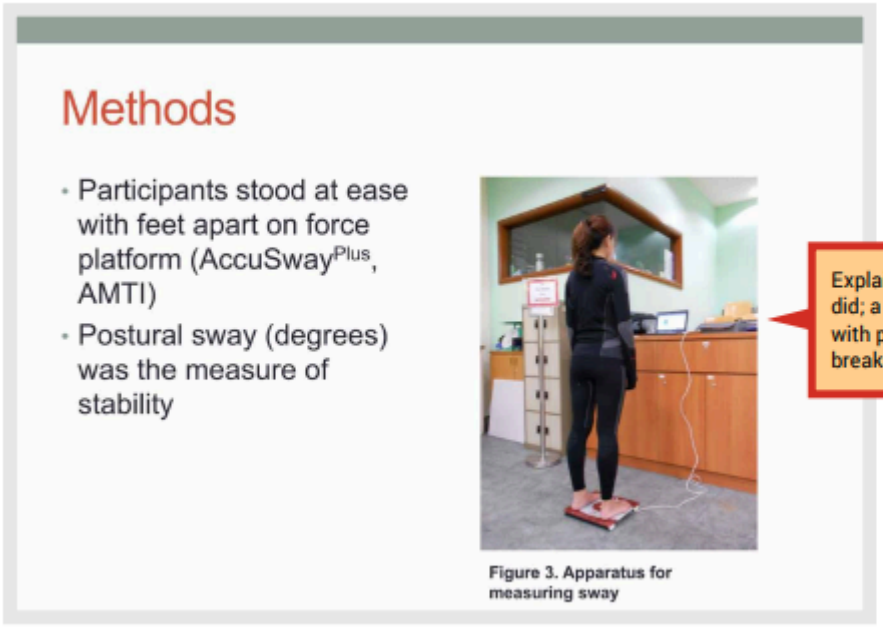
- We hypothesised that Stroop test performance would cause body sway to increase in healthy adults
- To determine if Stroop test performance would cause body sway to increase in healthy adults




As an example of how to expanding on the concise text shown in your slides during your presentation, you could say 'Each participant was measured under both conditions, with one-half of the subjects experiencing the conditions in reverse order'. Another example of how you could expand on the concise text shown on your slides during your presentation: 'Each participant stood on the force plate for 1 minute trials'.



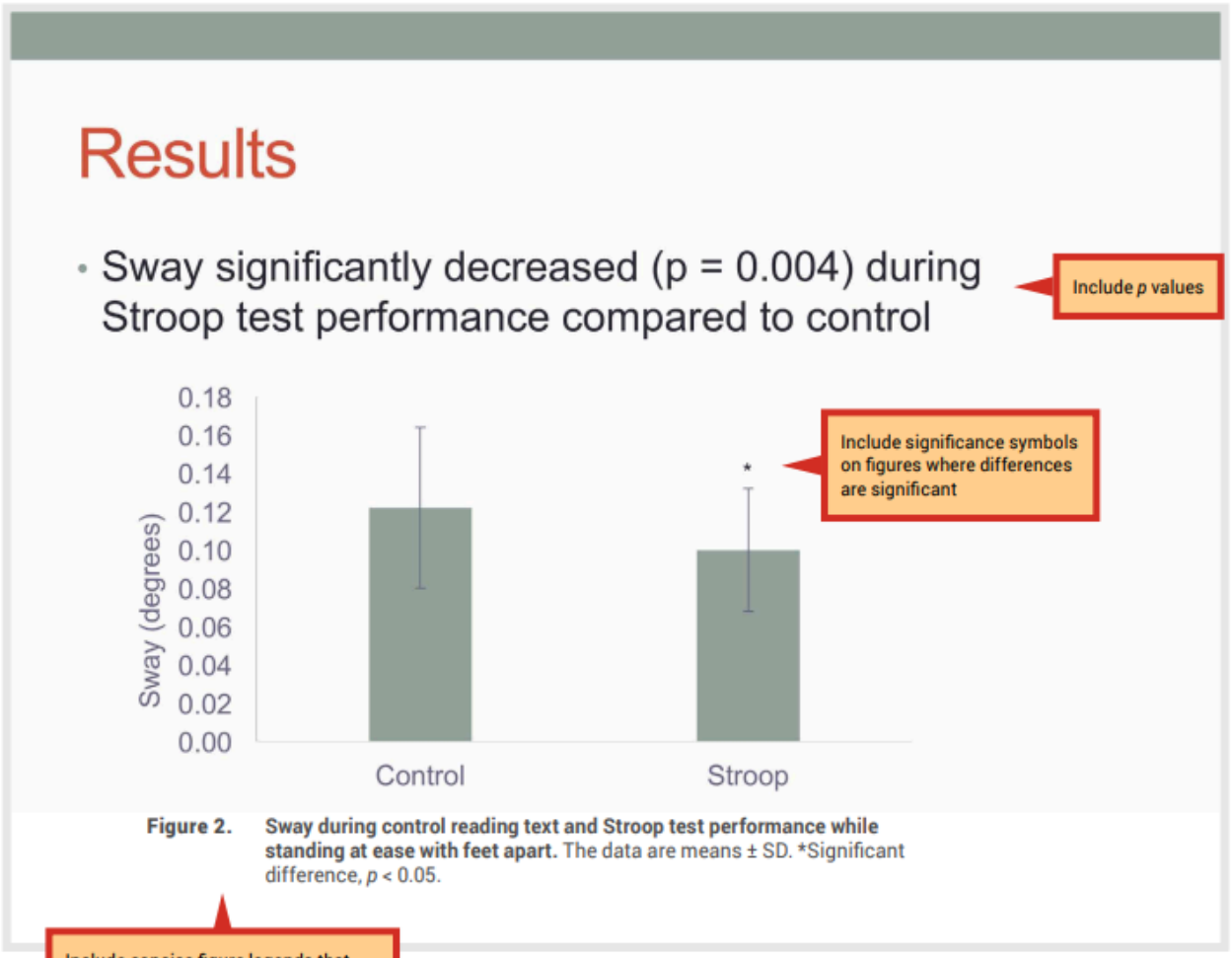

Use examples to help explain tests that the reader may not be familiar with; this also helps to break up the text




Explain what your participants did; a photo (taken and used with permission) will help to break up the text

## *Results*

You may choose to have separate Results and Discussion slides as in this example. Alternatively, where you have more than one major result to present, you may present each finding on a separate slide where you combine the Results and Discussion.

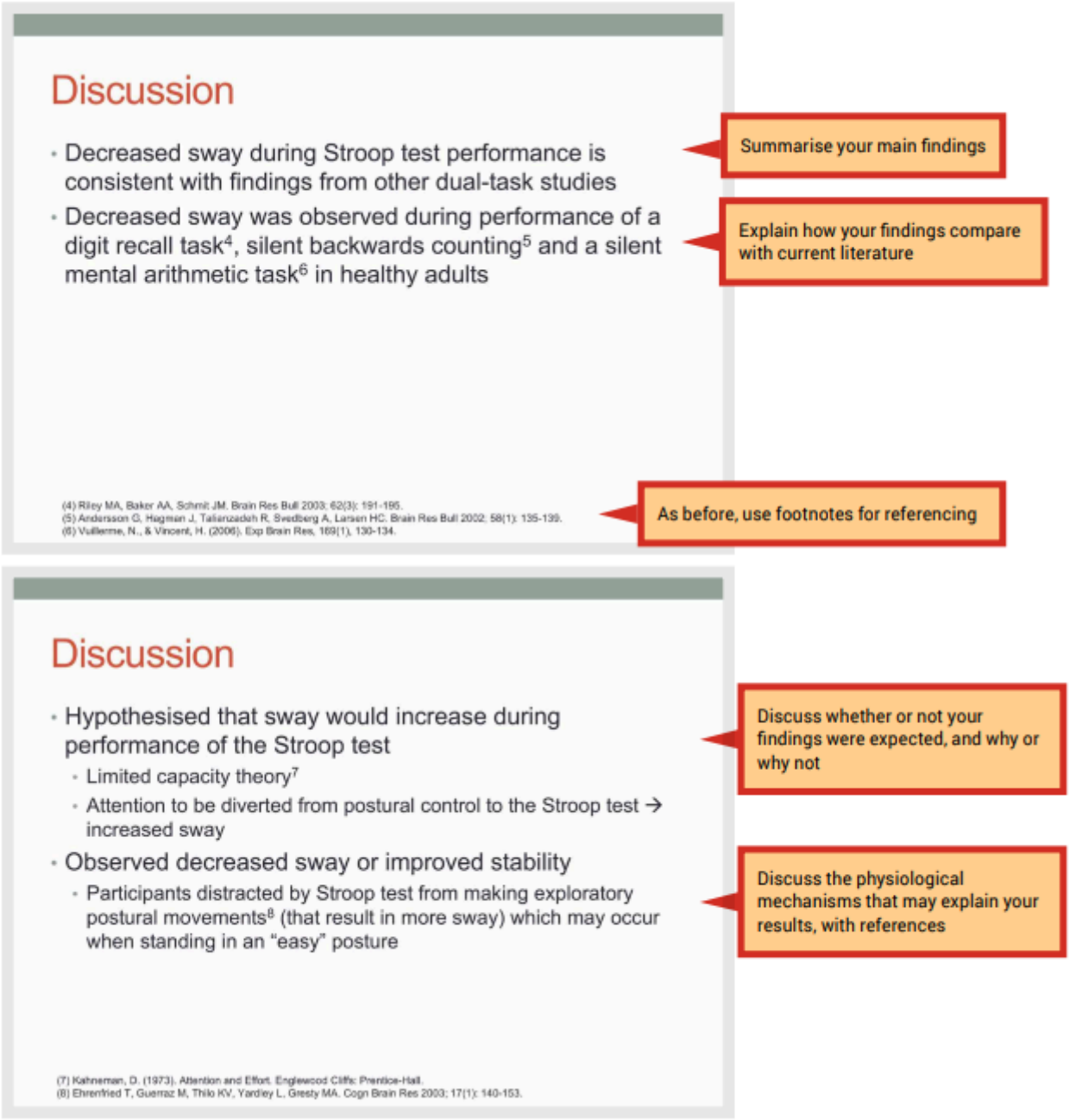



## *Discussion*

Keep this short, but make sure you still explain the following points:

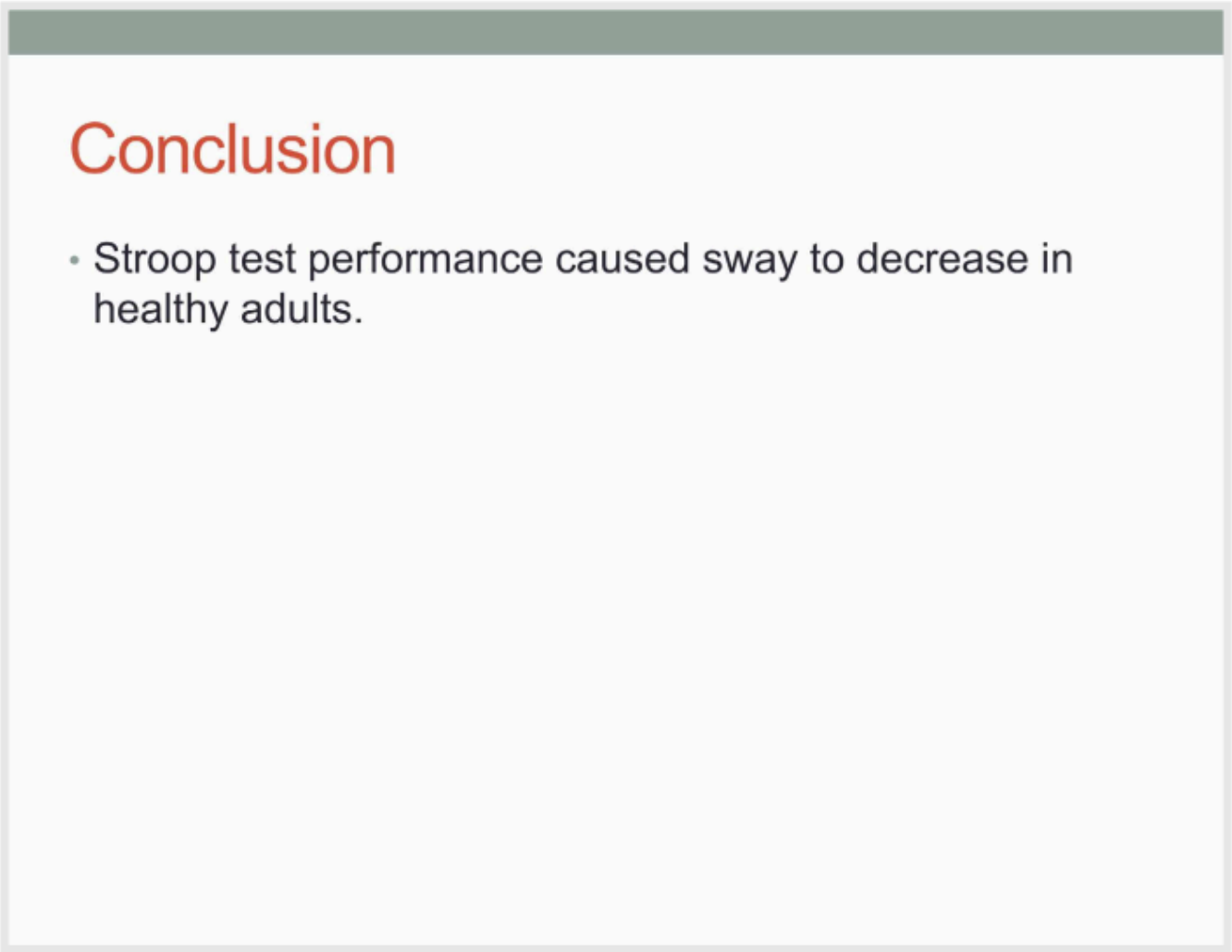
- How do your findings compare with what has been done previously in similar research?
- How do your results fit with your hypothesis? Were your findings expected? Why or why not?
- What physiological mechanism do you propose to explain the findings?

As before, use footnotes for referencing.




## *Conclusion*

Keep the conclusion concise. We suggest using the schema introduced in **Chapter 2** to write a short, direct conclusion that is consistent with your hypotheses and aims.




## Language use

You may want to begin work on the delivery aspect of your presentation by writing a script, but keep in mind the written word is very different than the spoken word. Reading your script aloud, to yourself and to a practise audience, will allow you to hear your speech so you can judge whether the language is appropriate for a presentation.

Remember that the way we write and speak are very different.

Try to make language choices that are imaginative, memorable and compelling, and enhance the effectiveness of your presentation. Watch presentations by people you admire and study the way they use language to engage the audience.

Resource

Ted talks has 1000s of presentations that you can use for inspiration.

Remember to consider the level of expertise of your audience when deciding on the language to use.

## Delivery

During your practise sessions, you can work on your delivery. A good presenter will be audible to everyone in the audience and will speak fluently, and not rely on notes. If you simply read your notes or presentation slides, it is very distracting to the audience. Practise will allow you to know your presentation well enough to leave the notes aside and speak to the audience.

Be aware of the time limit for your talk and be mindful of how close you are to the limit during your practice runs. You should make use of most or all of the allocated presentation time.

Remember to find out if there will be time allowed for questions after your talk, and ensure you consider this when preparing your presentation.

**Be conscious of your posture, use of gestures and eye contact, and vocal expressiveness. These elements will make your presentation compelling, and make you appear polished and confident.**

Further reading

Sahay, A., & Thangavelu, A. (2021). Presentations In Academic Success. https://usq.pressbooks.pub/academicsuccess/chapter/presentations/

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=219#h5p-27



## REFERENCES

Kon, M., Ohiwa, N., Honda, A., Matsubayashi, T., Ikeda, Tatsuaki., Akimoto, T., Suzuki, Y., Hirano, Y.,

& Russell, A.P. (2014) Effects of systemic hypoxia on human muscular adaptations to resistance exercise training. *Physiological Reports, 2*(6).

The Physiological Society. (2016). *Guidelines for writing a key points summary: Information for authors*. Retrieved August 24, 2016 from http://jp.msubmit.net/html/Keypoints_Guidelines.pdf.

CHAPTER 7

# *Writing a Literature Review*

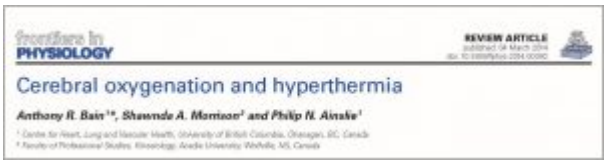
Hundreds of original investigation research articles on health science topics are published each year. It is becoming harder and harder to keep on top of all new findings in a topic area and – more importantly – to work out how they all fit together to determine our current understanding of a topic. This is where literature reviews come in.

In this chapter, we explain what a literature review is and outline the stages involved in writing one. We also provide practical tips on how to communicate the results of a review of current literature on a topic in the format of a literature review.

## 7.1 WHAT IS A LITERATURE REVIEW?

Literature reviews provide a synthesis and evaluation of the existing literature on a particular topic with the aim of gaining a new, deeper understanding of the topic.

Published literature reviews are typically written by scientists who are experts in that particular area of science. Usually, they will be widely published as authors of their own original work, making them highly qualified to author a literature review.


Frontiers in PHYSIOLOGY

REVIEW ARTICLE

Cerebral oxygenation and hyperthermia

Anthony R. Bain[1]*, Shawnda A. Morrison[2] and Philip N. Ainslie[1]

*Figure 7.1: Example of a review article published in Frontiers in Physiology.* ***Source:*** *Frontiers in Physiology, used under a CC BY 2.0 licence.*

However, literature reviews are still subject to peer review before being published. Literature reviews provide an important bridge between the expert scientific community and many other communities, such as science journalists, teachers, and medical and allied health professionals. When the most up-to-date knowledge reaches such audiences, it is more likely that this information will find its way to the general public. When this happens, – the ultimate good of science can be realised.

A literature review is structured differently from an original research article. It is developed based on themes, rather than stages of the scientific method.

In the article *Ten simple rules for writing a literature review*, Marco Pautasso explains the importance of literature reviews:

> Literature reviews are in great demand in most scientific fields. Their need stems from the ever-increasing output of scientific publications. For example, compared to 1991, in 2008 three, eight, and forty times more papers were indexed in Web of Science on malaria, obesity, and biodiversity, respectively. Given such mountains of papers, scientists cannot be expected to examine in detail every single new paper relevant to their interests. Thus, it is both advantageous and necessary to rely on regular summaries of the recent literature. Although recognition for scientists mainly comes from primary research, timely literature reviews can lead to new synthetic insights and are often widely read. For such summaries to be useful, however, they need to be compiled in a professional way (Pautasso, 2013, para. 1).

An example of a literature review is shown in **Figure 7.1.**

Video 7.1: What is a literature review? [2 mins, 11 secs]

Watch this video created by Steely Library at Northern Kentucky Library called 'What is a literature review? **Note:** Closed captions are available by clicking on the CC button below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=273#oembed-1

### Examples of published literature reviews

- Strength training alone, exercise therapy alone, and exercise therapy with passive manual mobilisation each reduce pain and disability in people with knee osteoarthritis: a systematic review
- Traveler's diarrhea: a clinical review
- Cultural concepts of distress and psychiatric disorders: literature review and research recommendations for global mental health epidemiology

## 7.2 STEPS OF WRITING A LITERATURE REVIEW

Writing a literature review is a very challenging task. **Figure 7.2** summarises the steps of writing a literature review. Depending on why you are writing your literature review, you may be given a topic area, or may choose a topic that particularly interests you or is related to a research project that you wish to undertake.

**Chapter 6** provides instructions on finding scientific literature that would form the basis for your literature review.

Once you have your topic and have accessed the literature, the next stages (analysis, synthesis and evaluation) are challenging. Next, we look at these important cognitive skills student scientists will need to develop and employ to successfully write a literature review, and provide some guidance for navigating these stages.

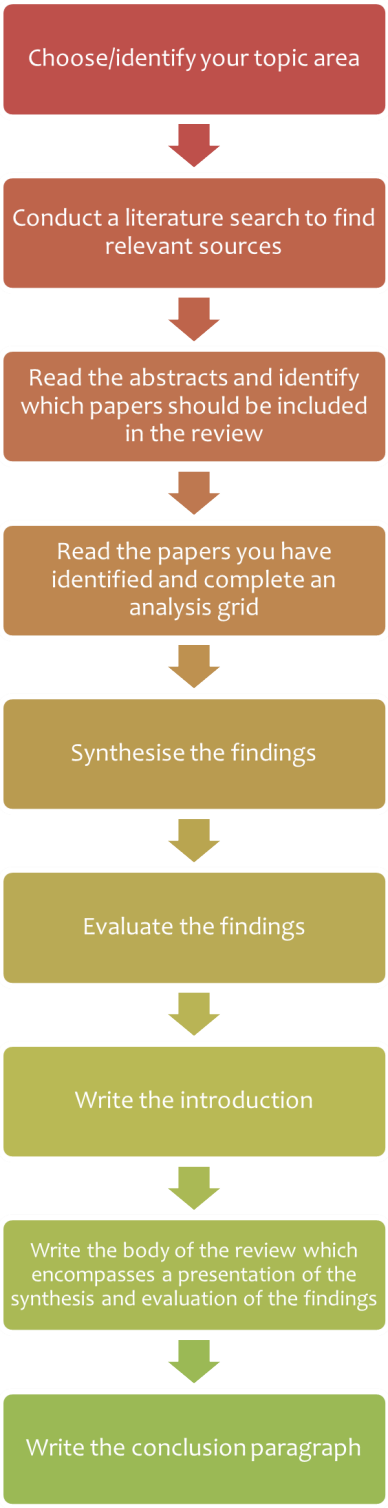



*Figure 7.2: Stages of writing a literature review.* ***Source:*** *Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

## Analysis, synthesis and evaluation

Analysis, synthesis and evaluation are three essential skills required by scientists and you will need to develop these skills if you are to write a good literature review (**Figure 7.3**). These important cognitive skills are discussed in more detail in **Chapter 9.**

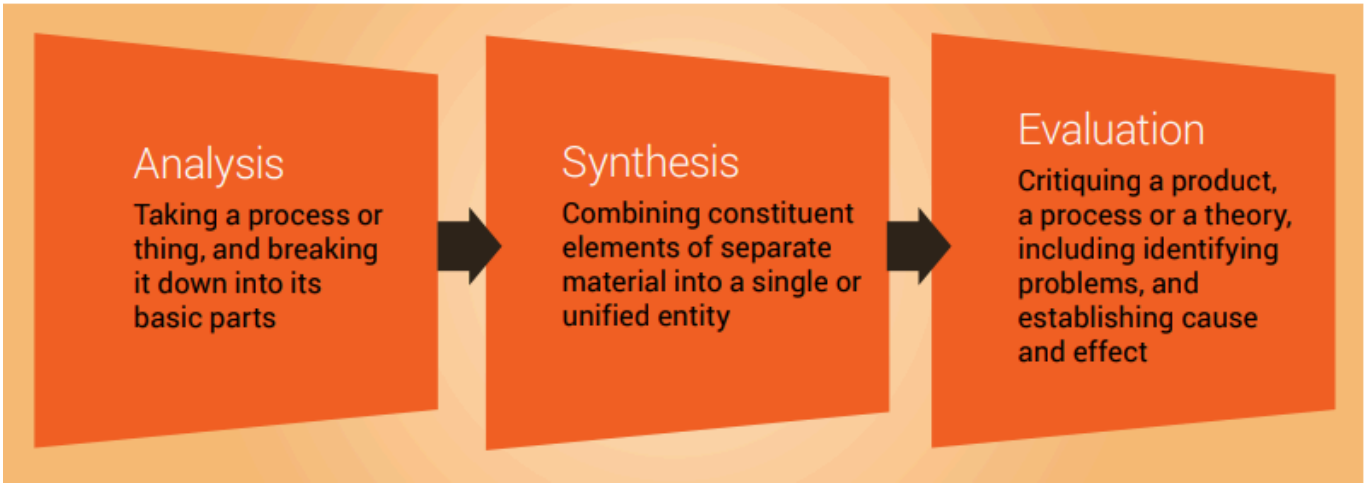



*Figure 7.3: Cognitive skills required for writing a literature review.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## *Analysis*

The first step in writing a literature review is to analyse the original investigation research papers that you have gathered related to your topic.

Analysis requires examining the papers methodically and in detail, so you can understand and interpret aspects of the study described in each research article.

An analysis grid is a simple tool you can use to help with the careful examination and breakdown of each paper. This tool will allow you to create a concise summary of each research paper; see **Table 7.1** for an example of an analysis grid. When filling in the grid, the aim is to draw out key aspects of each research paper. Use a different row for each paper, and a different column for each aspect of the paper (**Tables 7.2** and **7.3** show how completed analysis grid may look).

Before completing your own grid, look at these examples and note the types of information that have been included, as well as the level of detail. Completing an analysis grid with a sufficient level of detail will help you to complete the synthesis and evaluation stages effectively. This grid will allow you to more easily observe similarities and differences across the findings of the research papers and to identify possible explanations (e.g., differences in methodologies employed) for observed differences between the findings of different research papers.

### TABLE 7.1: EXAMPLE OF AN ANALYSIS GRID

| Author, date and rationale | Aim | Experimental design | Results | Conclusion | Evaluation of findings |
|---|---|---|---|---|---|
| [include details about the authors, date of publication and the rationale for the review] | [summarise the aim of the experiment] | [summarise the experiment design, include the subjects used and experimental groups] | [summarise the main findings] | [summarise the conclusion] | [evaluate the paper's findings, and highlight any terms or physiology concepts that you are unfamiliar with and should be included in your review] |

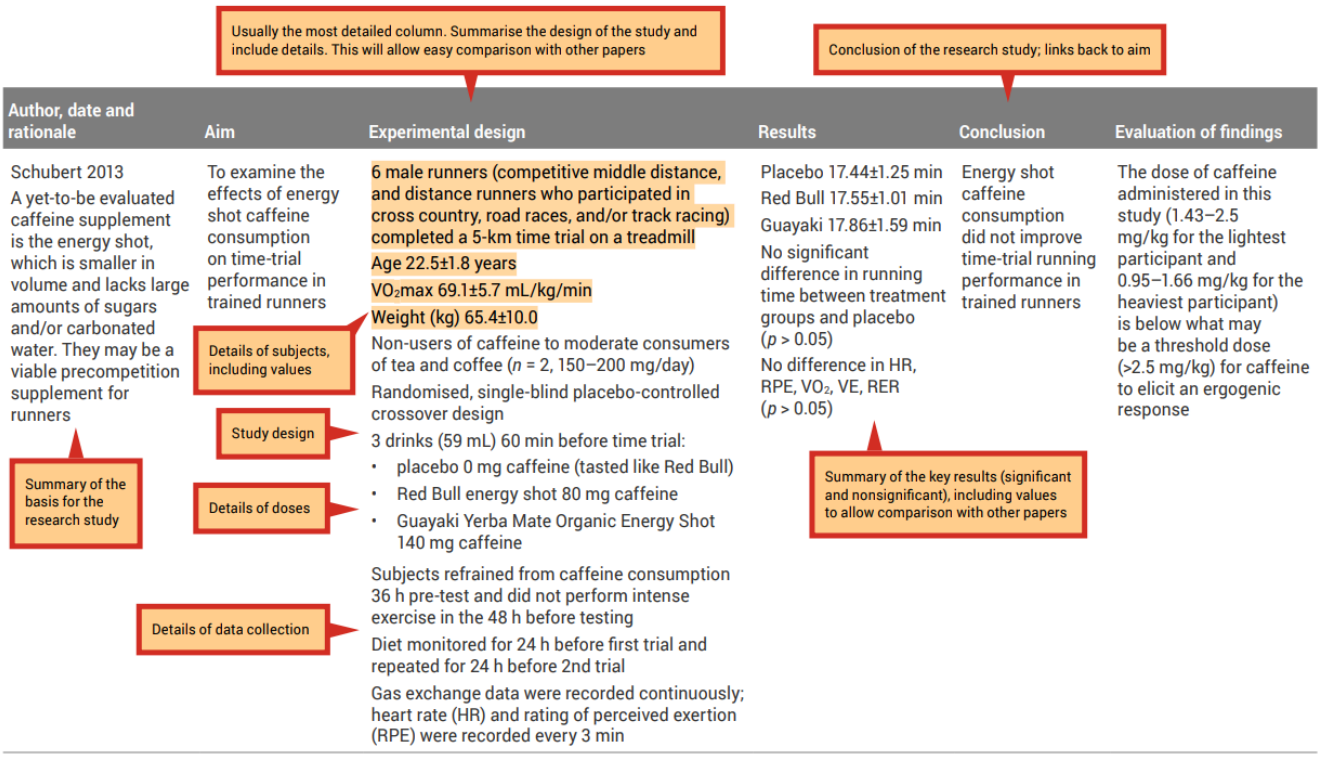



*Table 7.2: Sample filled-in analysis grid for research article by Schubert and colleagues. Source: Schubert, MM, Astorino, TA & Azevedo, JJL 2013, 'The effects of caffeinated 'energy shots' on time trial performance', Nutrients, vol. 5, no. 6, pp. 2062–2075. Adapted under a CC-BY 3.0 licence.*

## TABLE 7.3: SAMPLE FILLED-IN ANALYSIS GRID FOR RESEARCH ARTICLE BY PING AND COLLEAGUES

| Author, date and rationale | Aim | Experimental design | Results | Conclusion | Evaluation of findings |
|---|---|---|---|---|---|
| Ping 2010<br>The effect of chronic caffeine supplementation on endurance performance has been studied extensively in different populations. However, concurrent research on the effects of acute supplementation of caffeine on cardiorespiratory responses during endurance exercise in hot and humid conditions is unavailable | To determine the effect of caffeine supplementation on cardiorespiratory responses during endurance running in hot and humid conditions | 9 heat-adapted recreational male runners<br>Age 25.4±6.9 years<br>Weight (kg) 57.6±8.4<br>Non-users of caffeine (23.7±12.6 mg/day)<br>Randomised, double-blind placebo-controlled cross-over design (at least 7 days gap between trials to nullify effect of caffeine)<br>Caffeine (5 mg/kg) or placebo ingested as a capsule one hour before a running trial to exhaustion (70% VO2 max on a motorised treadmill in a heat-controlled laboratory (31 °C, 70% humidity)<br>Diet monitored for 3 days before first trial and repeated for 3 days before 2nd trial (to minimise variation in pre-exercise muscle glycogen)<br>Subjects asked to refrain from heavy exercise for 24 h before trials<br>Subjects drank 3 ml of cool water per kg of body weight every 20 min during running trial to stay hydrated<br>Heart rate (HR), core body temperature and rating of perceived exertion (RPE) were recorded at intervals of 10 mins, while oxygen consumption was measured at intervals of 20 min | Mean exhaustion time was 31.6% higher in the caffeine group:<br>• Placebo 83.6±21.4<br>• Caffeine 110.1±29.3<br>Running time to exhaustion was significantly higher (p 0.05) in the caffeine trial compared to the placebo trial<br>HR, core body temp, VO2 did not show any significant variation between trials (p > 0.05)<br>Caffeine ingestion significantly (p 0.05) decreased the RPE at 30, 40, 50 and 60 min. There were no differences (p > 0.05) between trials at 10 and 20 minutes, and at the end of the trial. | Ingestion of caffeine improved the endurance running performance, but did not affect heart rate, core body temperature, oxygen uptake or RPE. | The lower RPE during the caffeine trial may be because of the positive effect of caffeine ingestion on nerve impulse transmission, as well as an analgesic effect and psychological effect. Perhaps this is the same reason subjects could sustain the treadmill running for longer in the caffeine trial. |

Source: Ping, WC, Keong, CC & Bandyopadhyay, A 2010, 'Effects of acute supplementation of caffeine on cardiorespiratory responses during endurance running in a hot and humid climate', Indian Journal of Medical Research, vol. 132, pp. 36–41. Used under a CC-BY-NC-SA licence.

### *Synthesis*

Step two of writing a literature review is synthesis.

You will use the results of your analysis to find themes to build your literature review around. Each of the themes identified will become a subheading within the body of your literature review.

A good place to start when identifying themes is with the dependent variables (results/findings) that were investigated in the research studies.

**Synthesis describes combining separate components or elements to form a connected whole.**

Because all of the research articles you are incorporating into your literature review are related to your topic, it is likely that they have similar study designs and have measured similar dependent variables. Review the 'Results' column of your analysis grid. You may like to collate the common themes in a synthesis grid (see, for example **Table 7.4**).

| Theme number | Theme description |
|---|---|
| 1 | **Running performance**<br>Caffeine had no effect on running performance in the study by Schubert et al (2013). In contrast, caffeine ingestion improved running performance in the study by Ping et al (2010) |
| 2 | **Rating of perceived exertion (RPE)**<br>Caffeine had no effect on RPE in the study by Schubert et al (2013). In contrast, caffeine ingestion decreased RPE at 30, 40, 50 and 60 minutes in the study by Ping et al (2010) |
| 3 | **Heart rate (HR)**<br>Caffeine had no effect on HR in studies by Ping et al (2010) and Schubert et al (2013) |
| 4 | **Oxygen uptake**<br>Caffeine had no effect on total body oxygen consumption in studies by Ping et al (2010) and Schubert et al (2013) |

Theme = dependent variable common to at least 2 analysed research articles

Summary of the findings relating to this dependent variable

*Table 7.4: Sample filled-in synthesis grid for comparison of research articles based on Schubert et al. (used under a CC-BY 3.0 licence.) and Ping et al (used under a CC BY-NC-SA 4.0 licence).*

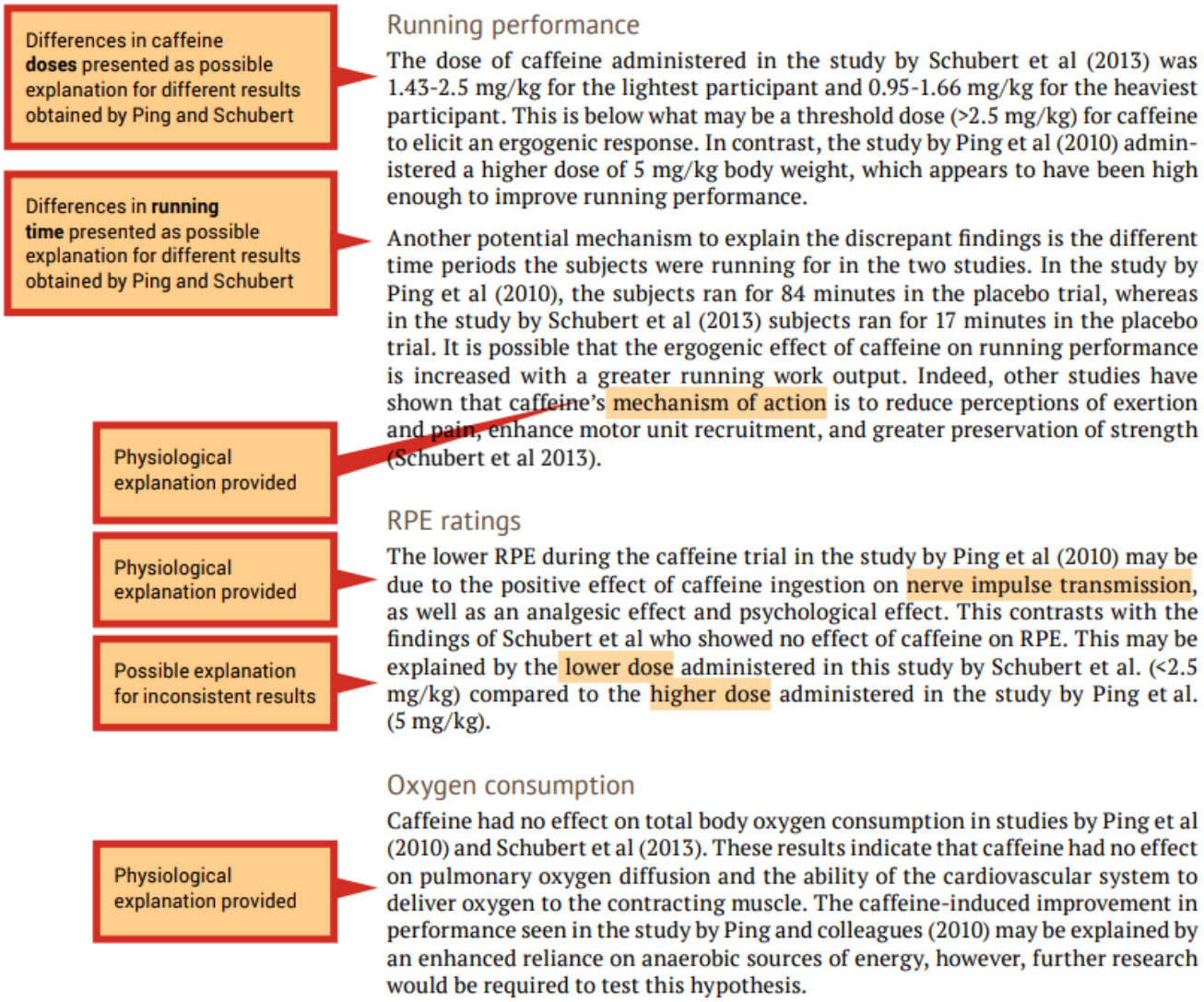
## *Evaluation*

Step three of writing a literature review is evaluation, which can only be done after carefully analysing your research papers and synthesising the common themes (findings).

During the evaluation stage, you are making judgements on the themes presented in the research articles that you have read. This includes providing physiological explanations for the findings. It may be useful to refer to the discussion section of published original investigation research papers, or another literature review, where the authors may mention tested or hypothetical physiological mechanisms that may explain their findings.

When the findings of the investigations related to a particular theme are inconsistent (e.g., one study shows that caffeine effects performance and another study shows that caffeine had no effect on performance) you should attempt to provide explanations of why the results differ, including physiological explanations. A good place to start is by comparing the methodologies to determine if there are any differences that may explain the differences in the findings (see the 'Experimental design' column of your analysis grid). An example of evaluation is shown in the examples that follow in this section, under 'Running performance' and 'RPE ratings'.

When the findings of the papers related to a particular theme are consistent (e.g., caffeine had no effect on oxygen uptake in both studies) an evaluation should include an explanation of why the results are similar. Once again, include physiological explanations. It is still a good idea to compare methodologies as a background to the evaluation. An example of evaluation is shown in the following under 'Oxygen consumption'.




## 7.3 WRITING YOUR LITERATURE REVIEW

Once you have completed the analysis, and synthesis grids and written your evaluation of the research papers , you can combine synthesis and evaluation information to create a paragraph for a literature review (**Figure 7.4**).

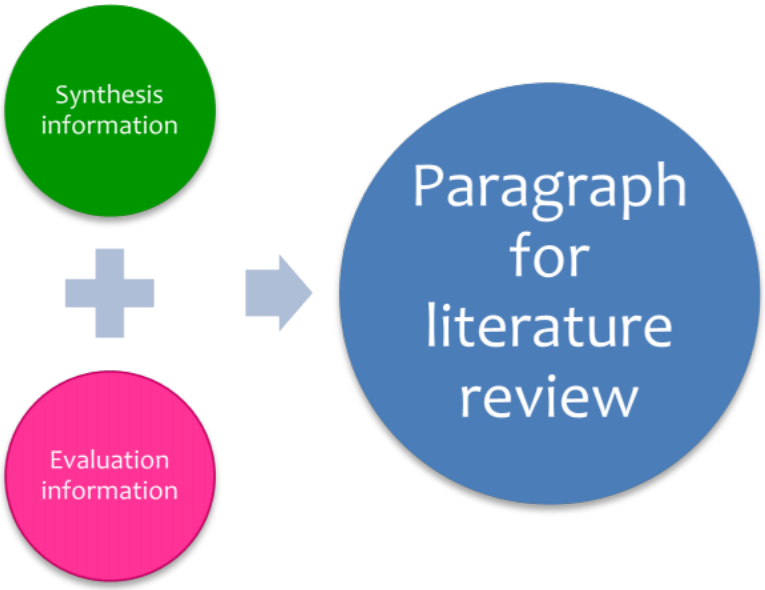
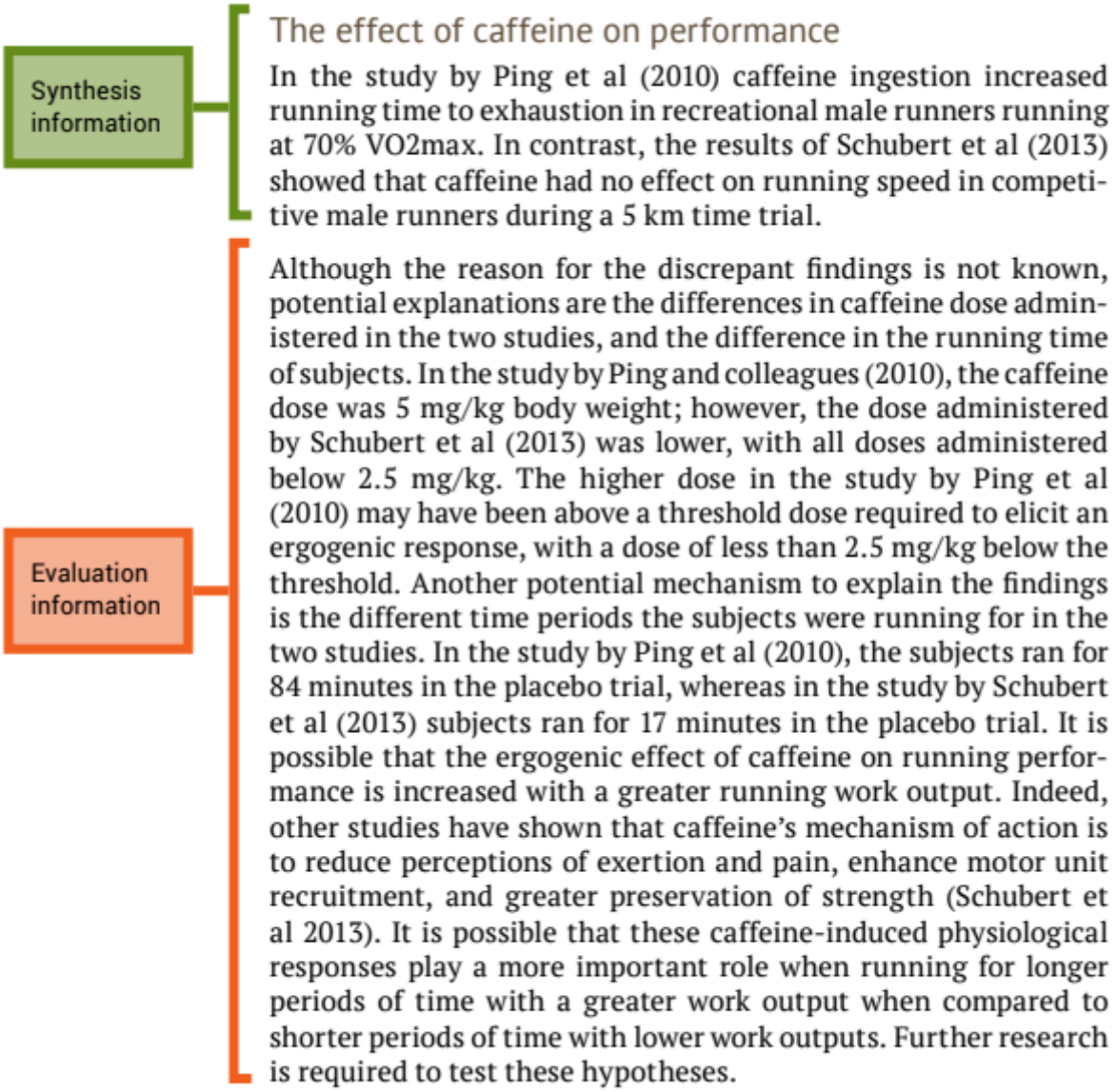



*Figure 7.4: Combining synthesis and evaluation information to write a paragraph of a literature review.* **Source:** *Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

The following paragraphs are an example of combining the outcome of the synthesis and evaluation stages to produce a paragraph for a literature review.

Note that this is an example using only two papers – most literature reviews would be presenting information on many more papers than this ( (e.g., 106 papers in the review article by Bain and colleagues discussed later in this chapter). However, the same principle applies regardless of the number of papers reviewed.




The next part of this chapter looks at the each section of a literature review and explains how to write them by referring to a review article that was published in *Frontiers in Physiology* and shown in **Figure 7.1.** Each section from the published article is annotated to highlight important features of the format of the review article, and identifies the synthesis and evaluation information.

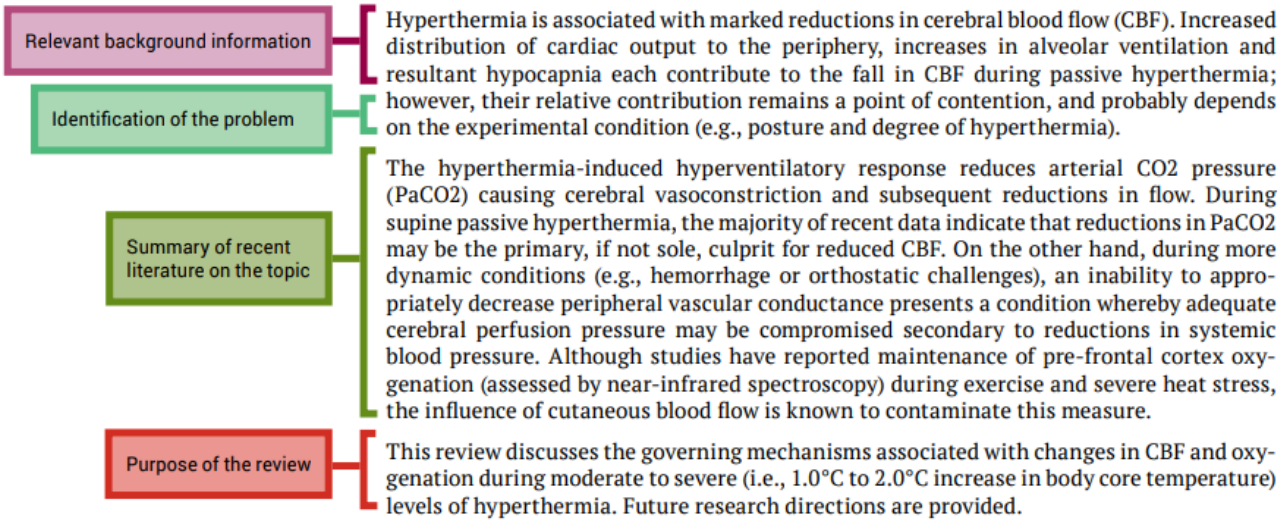
In the examination of each review article section we will point out examples of how the authors have presented certain information and where they display application of important cognitive processes; we will use the colour code shown below:

**Key**

Physiological significance | Aim | Methods | Conclusion | Background information
Synthesis | Summary synthesis | Evaluation, including hypotheses | Identification of the problem & gap in understanding

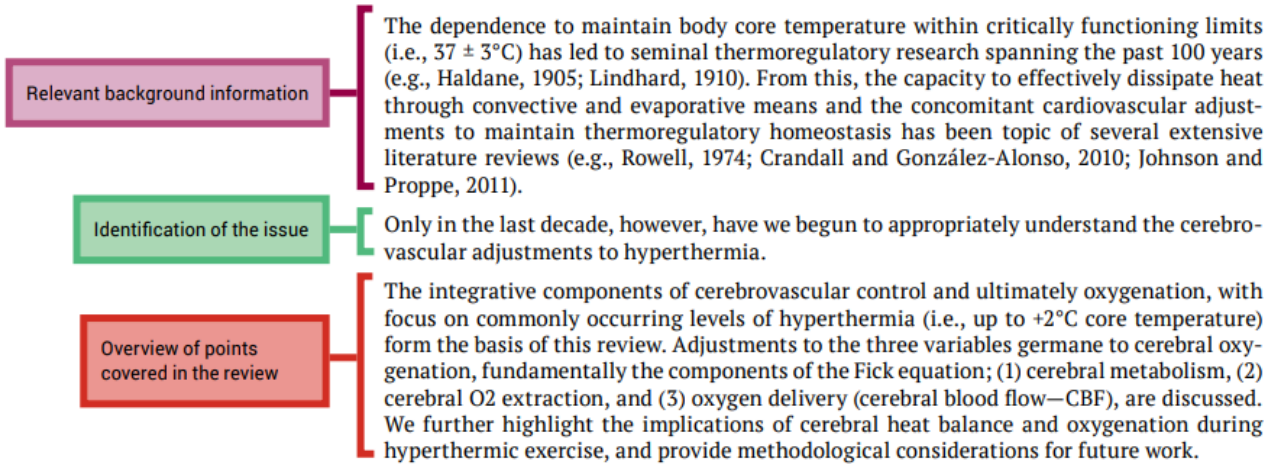
## *Abstract*

This should be one paragraph that accurately reflects the contents of the review article.

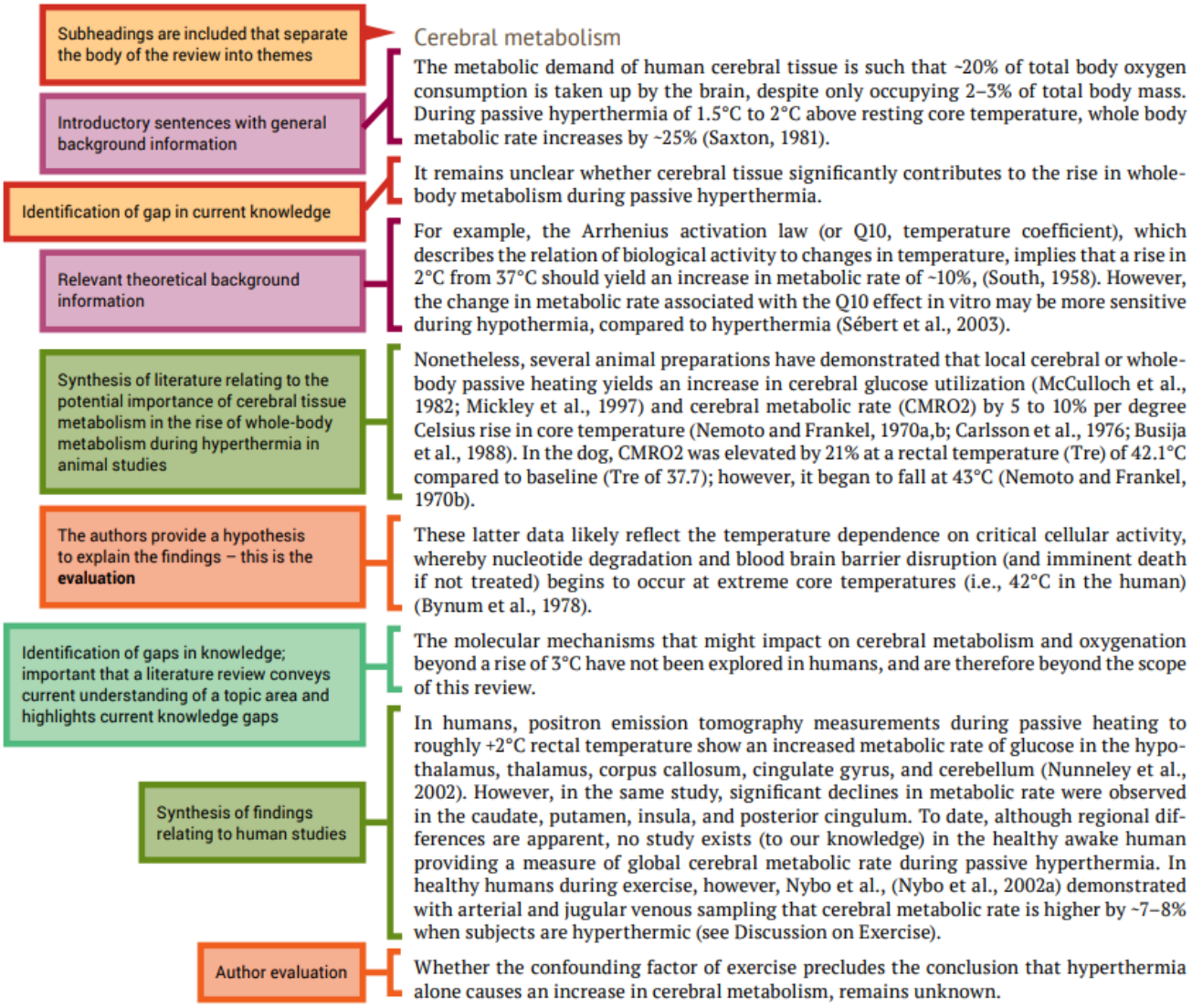


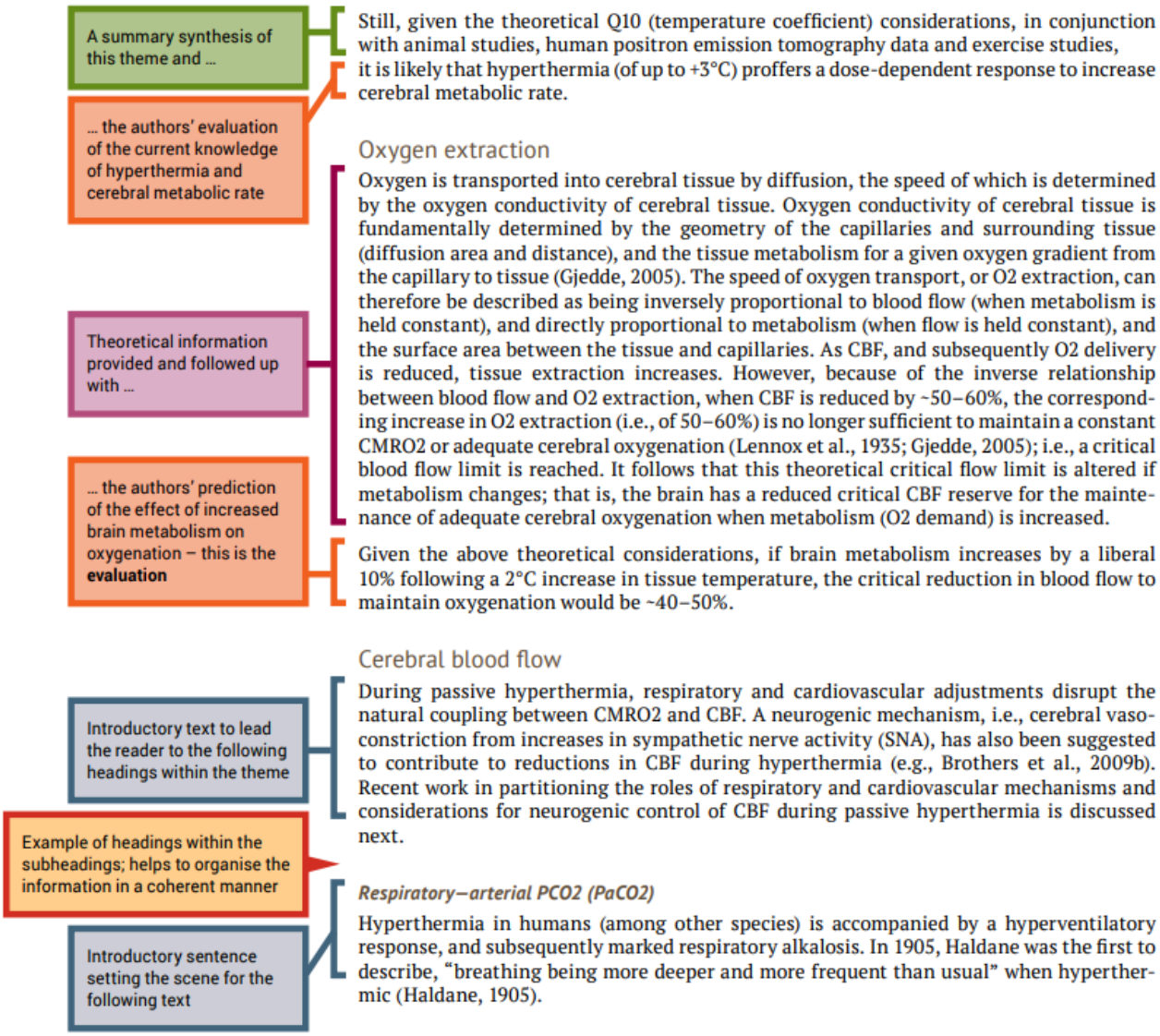

## *Introduction*

The introduction should establish the context and importance of the review



## Body of literature review






Still, given the theoretical Q10 (temperature coefficient) considerations, in conjunction with animal studies, human positron emission tomography data and exercise studies, it is likely that hyperthermia (of up to +3°C) proffers a dose-dependent response to increase cerebral metabolic rate.

## Oxygen extraction

Oxygen is transported into cerebral tissue by diffusion, the speed of which is determined by the oxygen conductivity of cerebral tissue. Oxygen conductivity of cerebral tissue is fundamentally determined by the geometry of the capillaries and surrounding tissue (diffusion area and distance), and the tissue metabolism for a given oxygen gradient from the capillary to tissue (Gjedde, 2005). The speed of oxygen transport, or O2 extraction, can therefore be described as being inversely proportional to blood flow (when metabolism is held constant), and directly proportional to metabolism (when flow is held constant), and the surface area between the tissue and capillaries. As CBF, and subsequently O2 delivery is reduced, tissue extraction increases. However, because of the inverse relationship between blood flow and O2 extraction, when CBF is reduced by ~50–60%, the corresponding increase in O2 extraction (i.e., of 50–60%) is no longer sufficient to maintain a constant CMRO2 or adequate cerebral oxygenation (Lennox et al., 1935; Gjedde, 2005); i.e., a critical blood flow limit is reached. It follows that this theoretical critical flow limit is altered if metabolism changes; that is, the brain has a reduced critical CBF reserve for the maintenance of adequate cerebral oxygenation when metabolism (O2 demand) is increased.

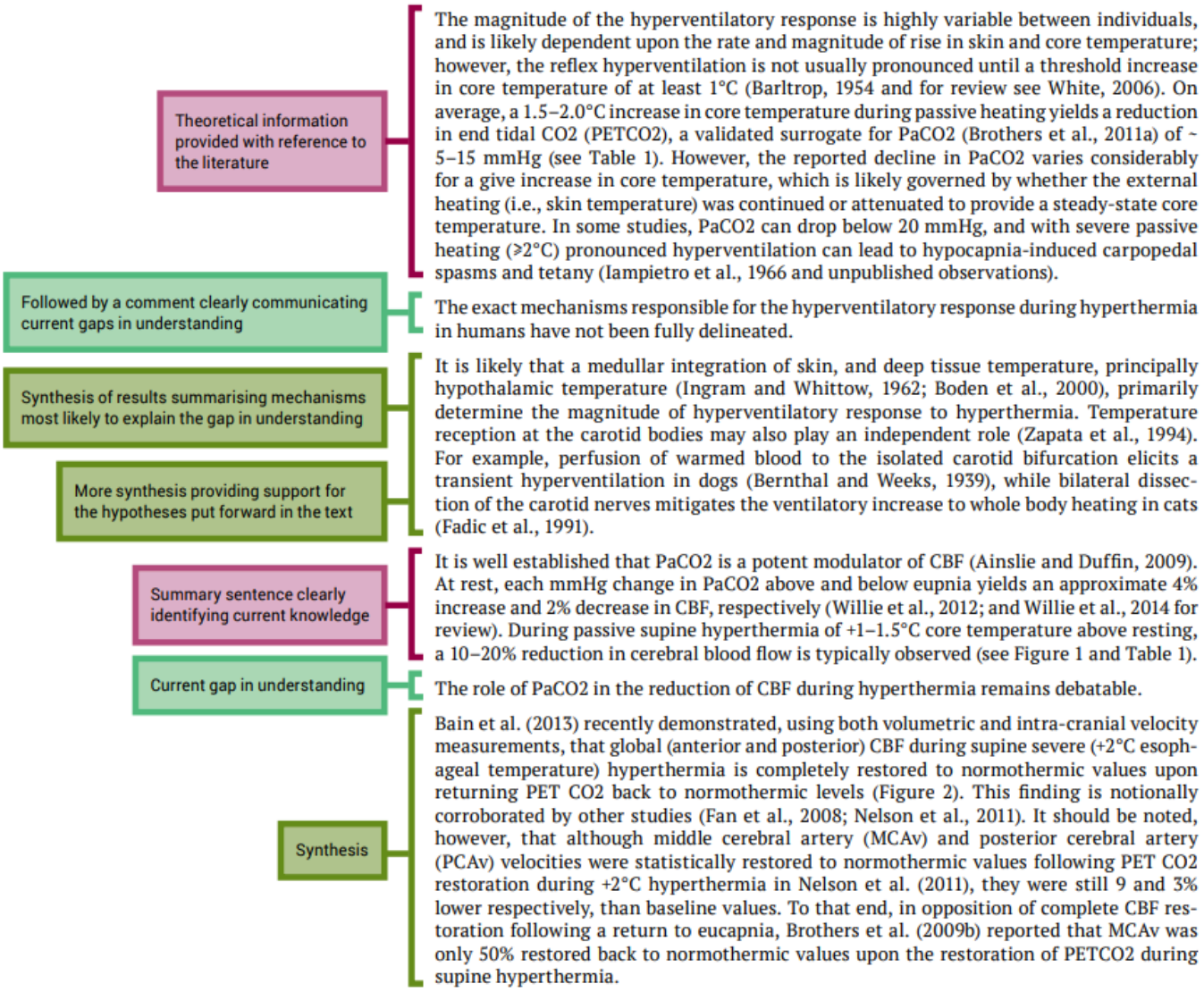
Given the above theoretical considerations, if brain metabolism increases by a liberal 10% following a 2°C increase in tissue temperature, the critical reduction in blood flow to maintain oxygenation would be ~40–50%.

## Cerebral blood flow

During passive hyperthermia, respiratory and cardiovascular adjustments disrupt the natural coupling between CMRO2 and CBF. A neurogenic mechanism, i.e., cerebral vasoconstriction from increases in sympathetic nerve activity (SNA), has also been suggested to contribute to reductions in CBF during hyperthermia (e.g., Brothers et al., 2009b). Recent work in partitioning the roles of respiratory and cardiovascular mechanisms and considerations for neurogenic control of CBF during passive hyperthermia is discussed next.

### *Respiratory–arterial PCO2 (PaCO2)*

Hyperthermia in humans (among other species) is accompanied by a hyperventilatory response, and subsequently marked respiratory alkalosis. In 1905, Haldane was the first to describe, "breathing being more deeper and more frequent than usual" when hyperthermic (Haldane, 1905).


Theoretical information provided with reference to the literature
The magnitude of the hyperventilatory response is highly variable between individuals, and is likely dependent upon the rate and magnitude of rise in skin and core temperature; however, the reflex hyperventilation is not usually pronounced until a threshold increase in core temperature of at least 1°C (Barltrop, 1954 and for review see White, 2006). On average, a 1.5–2.0°C increase in core temperature during passive heating yields a reduction in end tidal CO2 (PETCO2), a validated surrogate for PaCO2 (Brothers et al., 2011a) of ~ 5–15 mmHg (see Table 1). However, the reported decline in PaCO2 varies considerably for a give increase in core temperature, which is likely governed by whether the external heating (i.e., skin temperature) was continued or attenuated to provide a steady-state core temperature. In some studies, PaCO2 can drop below 20 mmHg, and with severe passive heating (>2°C) pronounced hyperventilation can lead to hypocapnia-induced carpopedal spasms and tetany (Iampietro et al., 1966 and unpublished observations).
Followed by a comment clearly communicating current gaps in understanding
The exact mechanisms responsible for the hyperventilatory response during hyperthermia in humans have not been fully delineated.
Synthesis of results summarising mechanisms most likely to explain the gap in understanding
It is likely that a medullar integration of skin, and deep tissue temperature, principally hypothalamic temperature (Ingram and Whittow, 1962; Boden et al., 2000), primarily determine the magnitude of hyperventilatory response to hyperthermia. Temperature reception at the carotid bodies may also play an independent role (Zapata et al., 1994). For example, perfusion of warmed blood to the isolated carotid bifurcation elicits a transient hyperventilation in dogs (Bernthal and Weeks, 1939), while bilateral dissection of the carotid nerves mitigates the ventilatory increase to whole body heating in cats (Fadic et al., 1991).
More synthesis providing support for the hypotheses put forward in the text
Summary sentence clearly identifying current knowledge
It is well established that PaCO2 is a potent modulator of CBF (Ainslie and Duffin, 2009). At rest, each mmHg change in PaCO2 above and below eupnia yields an approximate 4% increase and 2% decrease in CBF, respectively (Willie et al., 2012; and Willie et al., 2014 for review). During passive supine hyperthermia of +1–1.5°C core temperature above resting, a 10–20% reduction in cerebral blood flow is typically observed (see Figure 1 and Table 1).
Current gap in understanding
The role of PaCO2 in the reduction of CBF during hyperthermia remains debatable.
Synthesis
Bain et al. (2013) recently demonstrated, using both volumetric and intra-cranial velocity measurements, that global (anterior and posterior) CBF during supine severe (+2°C esophageal temperature) hyperthermia is completely restored to normothermic values upon returning PET CO2 back to normothermic levels (Figure 2). This finding is notionally corroborated by other studies (Fan et al., 2008; Nelson et al., 2011). It should be noted, however, that although middle cerebral artery (MCAv) and posterior cerebral artery (PCAv) velocities were statistically restored to normothermic values following PET CO2 restoration during +2°C hyperthermia in Nelson et al. (2011), they were still 9 and 3% lower respectively, than baseline values. To that end, in opposition of complete CBF restoration following a return to eucapnia, Brothers et al. (2009b) reported that MCAv was only 50% restored back to normothermic values upon the restoration of PETCO2 during supine hyperthermia.

Evaluation – theory presented that may explain inconsistent findings

Although difficult to reconcile, these divergent findings may be explained by the variability in "steady-state" CBF following baseline PETCO2 restoration. For example, although absolute CO2 reactivity appears to be maintained during hyperthermia (Low et al., 2008), the dynamics of the CBF response to eucapnic restoration will in part be determined by the magnitude of the hyperventilation response (and resultant respiratory alkalosis) (Ide et al., 2003). That is, those with a larger hyperventilatory response will likely require a longer time to reach steady-state CBF values upon restoration of baseline PaCO2 due to a larger extra-cellular pH gradient. Moreover, sustained hypoventilation may eventually lead to an adaptive response whereby restoration of baseline eucapnia will yield a temporary overshoot in CBF (compared to pre-stimulus values) (Ide et al., 2003).

Current gap in understanding

The mechanisms of this CBF overshoot remains unclear, but may involve changes in lactate and bicarbonate (Albrecht et al., 1987; Marder et al., 1990).

More evaluation

The transient magnitude of the CBF overshoot therefore probably depends upon the length of time and magnitude of the hypocapnia. It is clear that this can influence "steady-state eucapnic" CBF measures, and may explain the variable conclusions for the role of PaCO2 in reducing CBF during hyperthermia. Nonetheless, taken the most recent data (Nelson et al., 2011; Bain et al., 2013), it is more than likely that PaCO2 explains the majority of the CBF reduction during passive hyperthermia, at least when subjects are kept in the supine position.

Still, future research is warranted to better clarify this role.

Synthesis

In contrast to supine hyperthermia, during upright seated hyperthermia, Fujii et al. (2008) and Ross et al. (2012), found that MCAv is only partially restored back to normothermic levels upon restoration of PETCO2 with the addition of 5% CO2 to the inspired air. Furthermore, Nelson et al. (2011) found that head up tilt exacerbated the decline in MCAv and PCAv while hyperthermic, in the absence of significant further reductions in PETCO2.

Evaluation

It is therefore evident that, during hyperthermia, CBF is declined by increased hydrostatic pressure associated with posture (see Cardiovascular Section), independently of PaCO2.

*Do changes in PaCO2 alter tolerance time to a simulated hemorrhage?*

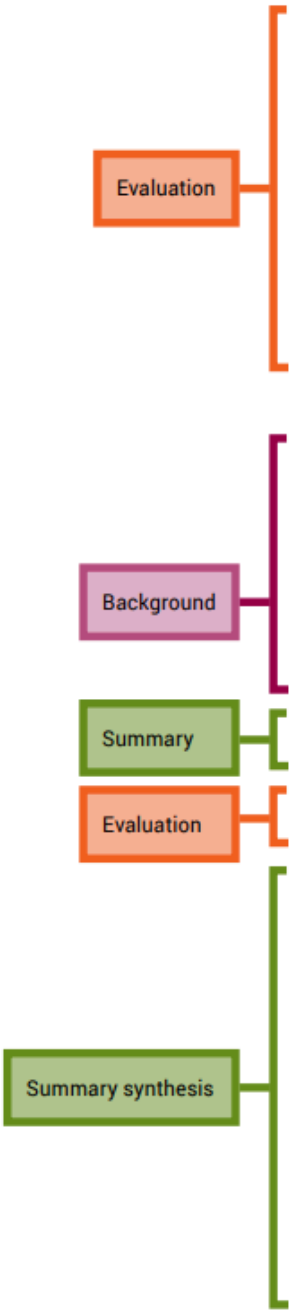
Summary synthesis

Tolerance time to a simulated hemorrhage is clearly reduced while hyperthermic compared to normothermic (Allan and Crossley, 1972; Wilson et al., 2006; Keller et al., 2009; Brothers et al., 2011b). Reductions in PaCO2 associated with hyperthermia-induced hyperventilation appear to have little influence on the reduced ability to withstand simulated hemorrhage (Lucas et al., 2013; Pearson et al., 2013).

Evaluation

This suggests that cardiovascular adjustments contribute more to tolerance time (i.e., minimum cerebral oxygenation levels before syncope) than baseline CBF during a graded hemorrhage simulation. This notion is supported by findings from our laboratory where tolerance to graded lower body negative pressure was unaltered even when baseline CBF was reduced by ~30% via administration of indomethacin, independently of changes in PaCO2 (Lewis et al., under review).

Evidence provided to support the hypothesis – also **evaluation**




Such findings may be attributed to the fact that simulated hemorrhage time is typically determined by the time elapsed before ethically low blood pressure levels (usually a SBP of <80 mmHg) are attained, rather than syncope itself. A perhaps more ecological stance is the view that a reduction in CBF at baseline, although not effecting tolerance time to simulated hemorrhage, effectively reduces the buffer zone for CBF to change before syncope occurs. As such, when PaCO2 and subsequently CBF, is reduced from hyperthermia, any condition eliciting a faster or larger perturbation in BP (i.e., a period when cerebral autoregulation is less effective) (Tzeng and Ainslie, 2013) compared to graded lower body negative pressure, may pose an increased risk of syncope.

It should be noted, however, that dynamic cerebral autoregulation, as indexed by steady-state linear transfer function analysis, appears to be maintained (Low et al., 2009) or perhaps even improved, with hyperthermia (Brothers et al., 2009a).

## Cardiovascular control

In order to promote heat loss via evaporative and convective means during severe passive hyperthermia, cutaneous blood flow can increase upwards of 25-fold (e.g., from ~300 to 7500 mL•min−1) (Rowell et al., 1969; Rowell, 1986). The large increase in cutaneous vascular conductance is met by concomitant increases in cardiac output (at times up to 13 mL•min−1) (Rowell et al., 1969; Rowell, 1986), accomplished almost exclusively via increases in heart rate. In turn, it is now well accepted that resting BP, and therefore perfusion pressure to the brain during passive, supine hyperthermia, is generally preserved, or only moderately decreased (see Crandall and González-Alonso, 2010 for a comprehensive review on the cardiovascular functioning during hyperthermia).

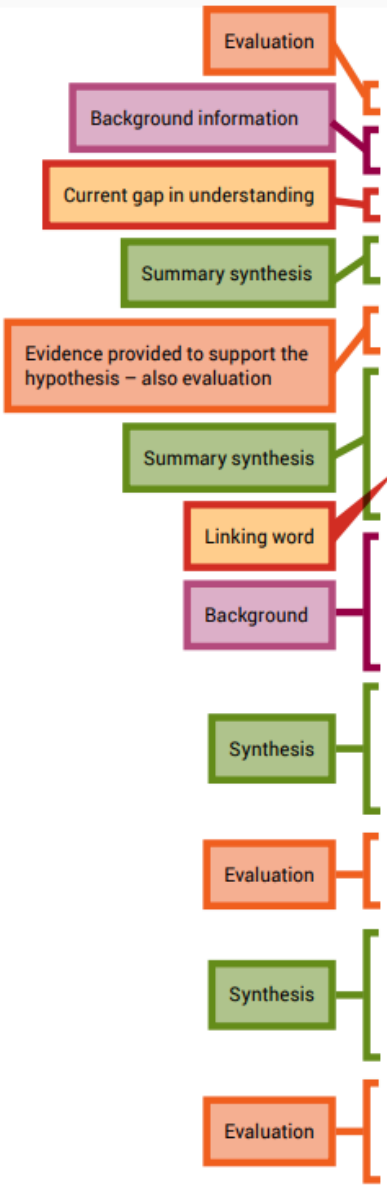
It is interesting to note, however, that BP estimations during passive hyperthermia vary considerably (see Table 1).

These variations likely reflect the difficulty in acquiring accurate BP measurements without measuring it intra-arterially during hyperthermia (Ganio et al., 2011).

Nonetheless, in contrast to passive supine hyperthermia, it is generally accepted that adequate BP is not maintained under dynamic hyperthermic conditions, e.g., with an orthostatic challenge or hemorrhage.

Any condition that compromises CBF maintenance inherently increases the risk of syncope/reduction of cerebral oxygenation. As mentioned, tolerance to an orthostatic challenge or simulated hemorrhage is reduced when hyperthermic (Allan and Crossley, 1972; Wilson et al., 2006; Keller et al., 2009; Brothers et al., 2011b).

Given that changes PaCO2 seem to play a negligible role in determining tolerance time to a simulated hemorrhage (see section Do changes in PaCO2 alter tolerance time to a simulated hemorrhage?), two key cardiovascular adjustments are likely responsible; (1) the inability to decrease systemic vascular compliance (SVC) (Wilson et al., 2002a; Ganio et al., 2012), and (2) a greater reduction in stroke volume for a given reduction in left ventricular filling pressure (i.e., a leftward shift of the operating point to a steeper portion on the Frank Starling curve) (Wilson et al., 2009).




Clearly, the former dictates the latter.

When normothermic, it is well established that SVC decreases during a simulated hemorrhage (Murray et al., 1968).

Why SVC does not also decrease when hyperthermic, is not entirely understood.

However, it is generally accepted that an inhibition of cutaneous vasoconstriction is likely at play (Crandall et al., 2010).

An improvement to orthostatic tolerance following acute skin cooling while hyperthermic lends evidence to this hypothesis (Wilson et al., 2002b).

The mechanisms of cutaneous vasculature control remains a complex field of study, riddled with redundant mechanistic pathways (for a review see Charkoudian, 2010).

Nonetheless, it appears that human physiology places a hierarchy for heat loss during hyperthermia, potentially to the detriment of adequate central blood volume and subsequently CBF/consciousness.

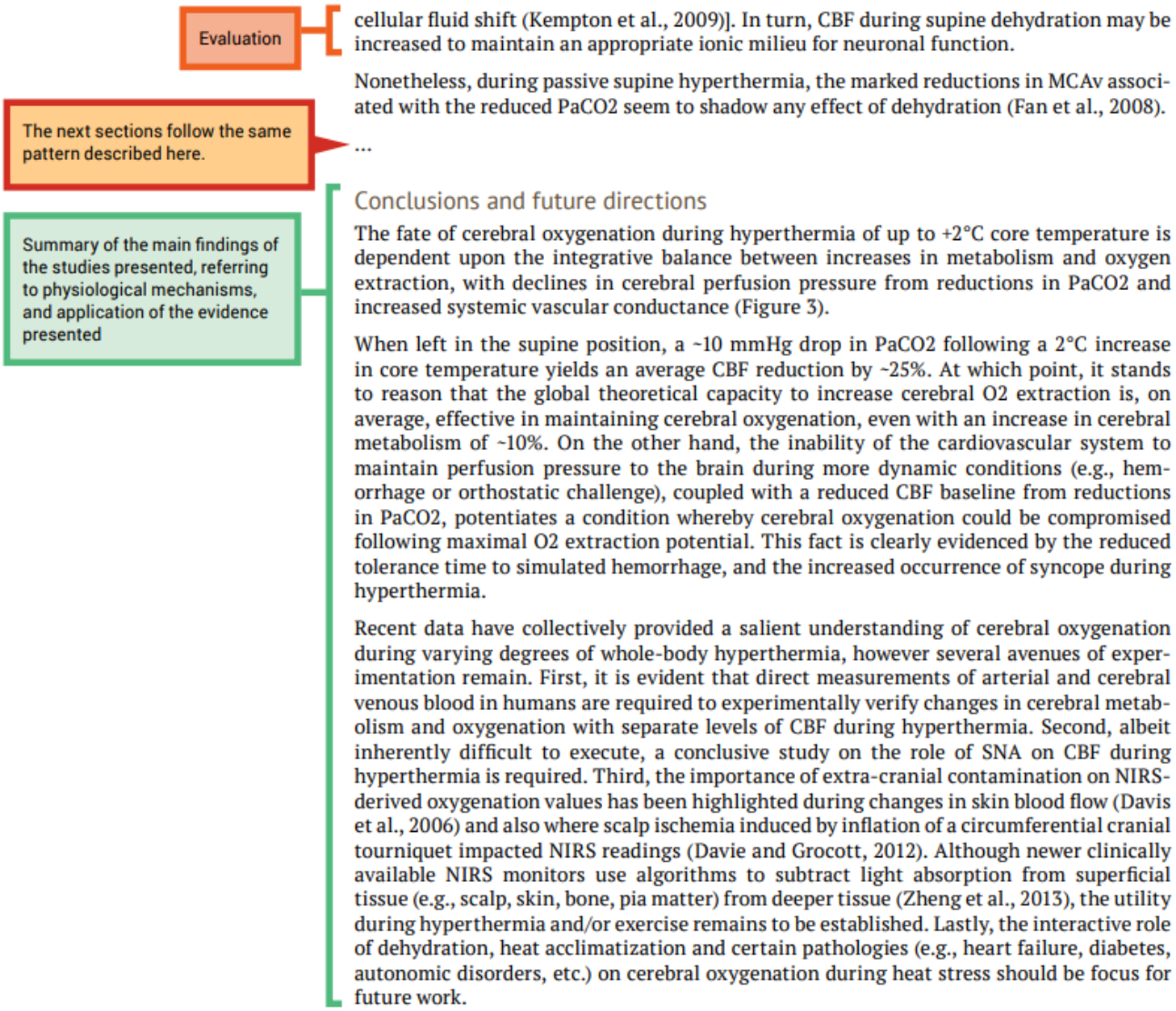
Dehydration (i.e., ≥2% loss of body mass) often follows prolonged sweating, and is therefore closely tied to hyperthermia. A major cardiovascular consequence of dehydration is a dose-dependent decrease in blood volume (Kempton et al., 2009). In turn, dehydration impairs the ability to maintain adequate central blood volumes, and thus CBF during an orthostatic challenge (Harrison et al., 1986; Romero et al., 2011).

Carter et al. (2006) demonstrated that the transient reductions in MCAv were larger upon standing from sitting when dehydrated (3.0% reduction in body mass), compared to euhydrated. Consistent with this finding, Moralez et al. (2012) demonstrated that dehydration (2.7% reduction in body mass) exacerbated the reductions in BP and MCAv upon standing following a 10-rep maximum leg press.

It is therefore reasonable to assume that when hyperthermia is coupled with dehydration, the ability to maintain adequate CBF is further reduced during orthostatic challenges or hemorrhage.

In contrast to the apparent reduction in CBF with an orthostatic challenge when dehydrated, Fan et al., (Fan et al., 2008) demonstrated that when subjects were supine, dehydration (1.5% reduction in body mass) increased resting MCAv by ~11%. When subjects were made hyperthermic, however, dehydration appeared to have little or no effect on the reduction in MCAv.

It is difficult to reconcile why MCAv was increased with normothermic dehydration compared to euhydration. Increases in CBF during passive supine dehydration may be related to the increased osmolality of extracellular fluid via cerebral cellular shrinkage [i.e., increased concentrations of solutes in the extracellular fluid cause an intra-to extra




cellular fluid shift (Kempton et al., 2009)]. In turn, CBF during supine dehydration may be increased to maintain an appropriate ionic milieu for neuronal function.

Nonetheless, during passive supine hyperthermia, the marked reductions in MCAv associated with the reduced PaCO2 seem to shadow any effect of dehydration (Fan et al., 2008).

...

Conclusions and future directions

The fate of cerebral oxygenation during hyperthermia of up to +2°C core temperature is dependent upon the integrative balance between increases in metabolism and oxygen extraction, with declines in cerebral perfusion pressure from reductions in PaCO2 and increased systemic vascular conductance (Figure 3).

When left in the supine position, a ~10 mmHg drop in PaCO2 following a 2°C increase in core temperature yields an average CBF reduction by ~25%. At which point, it stands to reason that the global theoretical capacity to increase cerebral O2 extraction is, on average, effective in maintaining cerebral oxygenation, even with an increase in cerebral metabolism of ~10%. On the other hand, the inability of the cardiovascular system to maintain perfusion pressure to the brain during more dynamic conditions (e.g., hemorrhage or orthostatic challenge), coupled with a reduced CBF baseline from reductions in PaCO2, potentiates a condition whereby cerebral oxygenation could be compromised following maximal O2 extraction potential. This fact is clearly evidenced by the reduced tolerance time to simulated hemorrhage, and the increased occurrence of syncope during hyperthermia.

Recent data have collectively provided a salient understanding of cerebral oxygenation during varying degrees of whole-body hyperthermia, however several avenues of experimentation remain. First, it is evident that direct measurements of arterial and cerebral venous blood in humans are required to experimentally verify changes in cerebral metabolism and oxygenation with separate levels of CBF during hyperthermia. Second, albeit inherently difficult to execute, a conclusive study on the role of SNA on CBF during hyperthermia is required. Third, the importance of extra-cranial contamination on NIRS-derived oxygenation values has been highlighted during changes in skin blood flow (Davis et al., 2006) and also where scalp ischemia induced by inflation of a circumferential cranial tourniquet impacted NIRS readings (Davie and Grocott, 2012). Although newer clinically available NIRS monitors use algorithms to subtract light absorption from superficial tissue (e.g., scalp, skin, bone, pia matter) from deeper tissue (Zheng et al., 2013), the utility during hyperthermia and/or exercise remains to be established. Lastly, the interactive role of dehydration, heat acclimatization and certain pathologies (e.g., heart failure, diabetes, autonomic disorders, etc.) on cerebral oxygenation during heat stress should be focus for future work.

## References

The reference section provides a list of the references that you cited in the body of your review article. The format will depend on the journal of publication as each journal has their own specific referencing format.

It is important to accurately cite references in research papers to acknowledge your sources and ensure credit is appropriately given to authors of work you have referred to. An accurate and comprehensive reference list also shows your readers that you are well-read in your topic area and are aware of the key papers that provide the context to your research.

It is important to keep track of your resources and to reference them consistently in the format required by the publication in which your work will appear. Most scientists will use reference management software to store details of all of the journal articles (and other sources) they use while writing their review article. This software also automates the process of adding in-text references and creating a reference list. In the review article by Bain et al. (2014) used as an example in this chapter, the reference list contains 106 items, so you can imagine how much help referencing software would be. **Chapter 5** shows you how to use EndNote, one example of reference management software.

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=273#h5p-29



## REFERENCES

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CHAPTER 8

# *Sharing Science with the Community*

Our society advances depending on the scientific literacy of its citizens. Scientifically literate individuals – such as science graduates – are trained to think scientifically. Not only do they understand scientific concepts, but they also know the nature of science and how we came to know what we do.

Thinking scientifically and critically – separating false claims that lack scientific evidence from scientifically valid information – is essential for everyday life. Individuals who are scientifically literate are able to make responsible decisions and participate in society in a positive way.

Citizens cannot be expected to improve their scientific literacy on their own, but many people can play a part in this important endeavour. This includes graduates from science, the medical and dental professions, the allied health disciplines, and other science-related fields including science journalism.

Improving the scientific literacy in our communities depends on the ability of science-educated individuals to reach out to our citizens and communicate science to them in such a way that has a long-lasting affect.

Your task is to inspire the community, fascinate them – and alert them when appropriate. Overall, you must help to educate the public and instil a passion that makes them want to learn more. This is how we can get people to change their behaviours in ways that will positively affect our future. Scientifically literate members of society will then go on to educate their own children, who will in turn instil scientific literacy in their children and so on.

> The general public is an audience with variable educational backgrounds and scientific understanding. Initially, it may be more difficult to communicate effectively with them than with your scientific peers. But this just takes practise. Many science curriculums focus on teaching facts. Communication tasks tend to be largely restricted to the scientific community.

In this chapter, you will learn more about what some high-profile scientists have to say on the importance of scientific literacy and science communication to the general public or non-expert audience (see **Box 8.1**). We will share some simple tips on how you can communicate effectively with the community at large to make your impact.

Box 8.1: What experts have to say about scientific literacy and science communication to the general public

Communicating science has been discussed by many eminent scientists and scientific associations.

### Professor Ian Chubb

**Professor Ian Chubb** was Australia's Chief Scientist in 2011–15. The Chief Scientist provides high-level independent advice to the Prime Minister and other ministers about science, technology and innovation.

> **Science has a marketing problem**. There's no question about that. The manner in which we get across the **sheer awesomeness of science** is often too muted. We're not constantly out there. We see single events as being enough and so, as I'm constantly saying to scientists, you know, just because you have a symposium or press release or a press conference, that's not enough in itself. – Ian Chubb

Regarding primary school children:

> [Renowned astronomer Carl Sagan] once said that we take these young children, who are totally curious and we then progressively beat it out of them. And I think that one of the things that we have to do is to maintain the sense that they can go to primary school and they can get shown science, visually, how it's practised, not taught out of a book, not just, you know, follow me, this is a principle. Why? Well it doesn't matter just learn it. That they're actually shown the awesomeness of science from a very early age and when that happens all the evidence is it sticks. – Ian Chubb

Regarding climate change:

> I would say part of plan B is to present the evidence in a way that's accessible to people who are interested but not necessarily trained in the disciplines of science. And that's where the message has got to go and I think that we started the run too late in that we said, you know, all of this work was done. It was kept largely – largely not exclusively – within the scientific community and it suddenly gets dumped on the public that this is a real problem that we've got to address right away. We should start earlier, we should work progressively through it, **take the public with us as we go** but we do need to make sure it's **not the typical techo and scientific talk** but it is, in fact, **without at all being patronising** but simply saying these are the real facts, this is what it means, these are the implications and we need to do something about it. – Ian Chubb

### Professor Suzanne Cory

**Professor Suzanne Cory** is one of Australia's most distinguished molecular biologists. She is currently a Research Professor in the Molecular Genetics of Cancer Division at The Walter and Eliza Hall Institute and a Vice-Chancellor's Fellow of The University of Melbourne.

> Every scientist I know who has been inspired to be a scientist has been inspired through a teacher ... Teaching science well at school is the way to inspire the next generation of scientists. **It's also absolutely critical to have a scientifically literate community**. So but science is still taught the old chalk and talk way, often by teachers who have not been trained in the subjects in which they're forced to teach. So we need to invest in this country in training more and better science teachers and give them the resources to teach with and we need to teach them ... we need to teach our students by doing science, which is what you were saying and the Government has invested in two programs that the Academy of Science has developed over the last the years. There's a Primary Connections Program and there's Science By Doing for junior secondary schools. Those programs are totally transforming the way science is taught in schools, they need to be in every school in this country. – Suzanne Cory

Professor Ian Chubb and Professor Suzanne Cory's comments are taken from a special science edition of the ABC program *Q&A* called 'Science: precious petals to passionate teachers' (Jones et al., 2014). The comments here are taken from the 'Keeping students interested' and 'Climate change' segments.

### The Australian Academy of Science

The mission of the Australian Academy of Science (AAS, 2015) is to:

- champion Australian scientific excellence
- promote and disseminate scientific knowledge
- provide independent scientific advice

The AAS aims to benefit of Australia and the world (Australian Academy of Science, 2015). Scientists from the AAS found that the number of students studying science in years 11 and 12 is declining: in 2012 only 50% of year 12 students studied science (Goodrum et al., 2012). The authors recommended improving student engagement in science studied in years 7–10 to generate interest that will increase numbers of senior high school students continuing to study science. The AAS also recognises the importance of developing **scientific literacy in primary school students,** which led to the implementation of the **Primary Connections** initiative that aims to engage students in science at a younger age (Primary Connections, 2013).

### The National Science Foundation

The National Science Foundation (NSF, 2015) is an independent federal agency created by the United States Congress in 1950 to:

- promote the progress of science
- advance the national health, prosperity and welfare
- secure the national defense.

In 2006, the NSF reported that the American **public had a limited understanding of science** and technology, despite being supportive of the fields (Kahlor & Stout, 2010). The public's lack of knowledge about science can have far-reaching negative implications, including that they are unable to evaluate scientific information presented by public and allied health agencies, pharmaceutical companies, journalists and medical practitioners (Kahlor & Stout, 2010).

For the student scientist, it should be clear that one of the many important things that we need to achieve is an increase in the scientific literacy of our citizens, if humanity is to have the best possible future.

## 8.1 WHERE TO START

So what are some relatively straightforward and simple ways that people can communicate both formally and informally to the general public – in a way that is effective? Although there is no definite and correct answer, the suggestions in **Figure 8.1** should steer you in the right direction.

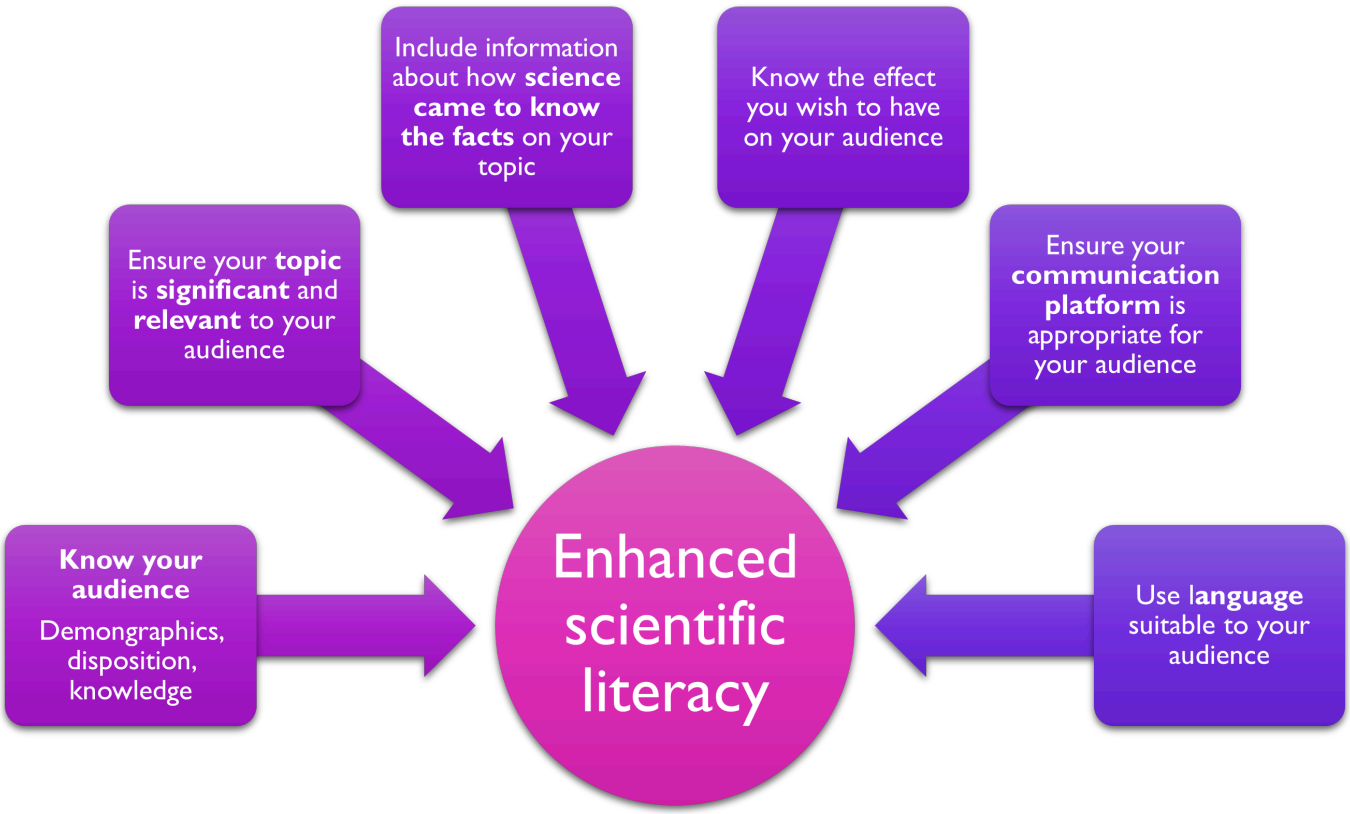


*Figure 8.1: How to enhance scientific literacy in the general public.* ***Source:*** *Image by Nikki Andersen adapted from La Trobe University, and used under a CC-BY-NC-SA 4.0 licence.*

To help you decide what to do next, choose your starting point – one of concept, audience or mode – and refer to **Figure 8.2.**

If you are interested in a particular concept, follow the blue arrows in **Figure 8.2.**

- Who needs to know about this concept?
- What mode of communication is this audience most likely to respond to?

If you have identified an audience you would like to communicate to, follow the red arrows in **Figure 8.2.**

- What is a concept this audience needs to know about?
- How do you best communicate to this audience?

If you have identified a mode of communication you would like to use, follow the yellow arrows in **Figure 8.2.**

- Who would be most likely to respond to this mode of communication?
- What is a concept this audience needs to know about?


*Figure 8.2: Relationship between concept, audience and mode when communicating science.* ***Source:*** *Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

## Know your audience

Successful science communicators must be able to recognise and understand their target audience, and make the science accessible to them. Examples of discrete audiences include:

- preschool children
- primary school children
- secondary school students
- university students
- patients diagnosed with a particular condition
- family members of patients diagnosed with a particular condition
- older people
- people from a particular demographic (e.g. non-English speaking background)
- inactive individuals
- overweight individuals
- smokers

As you can see, your audience can vary a lot!

To narrow down and understand your audience, conduct an audience analysis. This will allow you to communicate with them more effectively.

Resources

One of the resources for *The writer's workshop: skills for success* course offered by the Business Administration Program at the University of Washington is a series of questions to help you analyse your audience (University of Washington, 2014). This resource lists three main

areas to consider when analysing your audience: demographics, disposition and knowledge. These questions are written in reference to a reading audience, but they apply to all audience types. The resource also suggests that you consider how each of the factors you identify affects your readers' attitudes, expectations, and opinions about you and your topic.

The Australian Bureau of Statistics website allows you to access national and regional statistics on the Australian population. Results from the most recent census as well as statistics on social trends are available.

### Ensure that your topic is significant and relevant to your audience

To have a significant and positive impact on improving scientific literacy in the community, your choice of topic should be contemporary and highly relevant to your audience. Equally as important to this, you need to communicate in such a way that – in the end – the audience truly believes the issue really matters to them. If your audience believes this, their attitude and behavior will start to change in line with what the science is telling us.

Remember that members of the general public are likely to be more interested in the implications and impact of science, rather than the nitty-gritty that we talk about with our scientific peers.

A good way to determine why a particular concept is important is by asking yourself that exact question. Is it related to a significant health issue for the Australian population, such as mental health, inactivity, poor diet, diabetes mellitus, cardiovascular disease or cancer? Is it an important global issue, such as climate change?

At the global level, there are myriad issues that the world faces. Energy, food and water security; climate change; biodiversity; infectious diseases and conditions such those caused by the Zika COVID-19 virus and Ebola virus; health issues such as cardiovascular health and diabetes; air pollution; and mental health for trauma survivors. These are only a small percentage of the world's most important problems – many more need to be communicated to the public.

Resource

The Australian Institute of Health and Welfare website has a list of national health priority areas, as well as data on a range of health and welfare issues sorted by subject.

Contrary to what you might think, science professionals are yet to successfully communicate these issues adequately to the general public. If we improve our science communication to the public and increase scientific literacy, we increase our chances of successfully confronting these challenges both domestically and globally.

**Box 8.2** provides some examples of topics, target audiences and desired outcomes.

Box 8.2: Examples of topics and appropriate target audiences

Never forget that the knowledge we have is because of science. Wherever possible, include relevant information on how we came to know what we do. In other words, how has the science evolved that has led us to our current understandings on the issue?

It's also important to know what types of attitude and behavior changes the science is telling us should take place. Your communication should help the population move towards these changes, along with an understanding of why the changes should occur.

#### Type II diabetes prevention

**Audience and task**: Communicate to a group of newly joined Weight Watchers members on how they can reduce their risk of developing Type II diabetes. These individuals will be overweight and at an increased risk of developing the disease.

**Desired outcome**: increased activity and weight loss, and decreased risk of developing type II diabetes in these individuals, combined with an understanding of how poor diet and inactivity increases the risk of developing diabetes.

### Cardiovascular disease prevention

**Audience and task**: Communicate to the general public on what the risk factors are for development of cardiovascular disease and what can be done to reduce the risk. Cardiovascular disease is a leading cause of death in Australia, so in this case it would be appropriate to pitch to the general public.

**Desired outcome**: increased activity, weight loss in overweight individuals, a healthier diet rich in antioxidants, quit smoking or never taking it up, decreased risk of developing cardiovascular disease, combined with an understanding of the science behind the risks of cardiovascular disease.

### The benefits of quitting smoking

**Audience and task**: Communicate to the smoking population on what the dangers of smoking are and some tips on how to stop.

**Desired outcome**: Quit smoking and understand the health benefits of doing so.

### The benefits of not taking up smoking

**Audience and task**: Communicate to a group of primary school children on what the dangers of smoking are and some tips on how not to take it up.

**Desired outcome**: reduce rates of smoking uptake in our young population and an understanding of the health benefits of not taking up smoking.

### The benefits of regular physical activity

**Audience and task**: Communicate to a group of primary school children on the benefits of regular physical activity before bad habits set in.

**Desired outcome**: increased activity levels reducing risk of cardiovascular disease, diabetes and obesity, combined with an understanding of why exercise helps do this.

### How to prevent the spread of the Zika virus

**Audience and task:** Communicate to the general public in South America and North America on what science tells us about the best way to treat and prevent the spread of Zika virus.

**Desired outcome**: decreased spread of Zika virus, combined with an understanding of how Zika virus spreads.

## Ensure your communication platform is appropriate for your audience

Consider the vast array of available platforms for communicating about your topic to your audience:

- websites
- posters and brochures
- newspaper and magazine articles
- songs, games and videos
- classroom activities
- podcasts and mobile apps
- artworks

It is important to engage with the audience in a genre appropriate to that audience. For example, if you would

like to create a video to communicate your topic, would it be best to select a topic that would be of interest to 15–20 year olds or to 60–70 year olds? Consider how you would justify your decision. **Box 8.3** provides a list of resources that can help you decide on your communication platform.

Regardless of the communication platform that you choose, take care to present your communication piece professionally – this is likely to have a greater impact on your audience.

Box 8.3: Useful programs for creating communication pieces

There are many useful programs available for creating communication pieces. Many of these tools are easy to use and produce a professional looking product. This is not an exhaustive list of useful software but it's certainly a great place to start:

- Adobe Spark can help you create social graphics, web stories and animated videos – in minutes
- Microsoft Sway helps you make and share interactive reports, presentations and stories
- iMovie or Windows Movie Maker come standard with your Apple or PC
- Moovly allows you to make animated videos, presentations, infographics and videoclips
- Visme allows you to create presentations and infographics
- Audacity is a free, sophisticated audio recording and editing software
- Canva is a free-to-access website that allows you to do simple graphic design, and create flyers, posters and presentations
- PowToon allows you to create animated videos and presentations
- Videoscribe offers a 7-day free trial to create whiteboard-style animations

Which platform to use?

- The Australian Bureau of Statistics published a report called *Household use of information technology, Australia*
- The Australian Communications and Media Authority (ACMA) published a report called *Smartphones and tablets take-up and use in Australia*
- Roy Morgan's research posts details on readership statistics for major Australian newspapers
- YouTube provides summary statistics on viewers of content on their site

## Use language suitable to your audience

To successfully communicate your topic or concept to your target audience, you must consider the unique characteristics of your audience and their knowledge in the area.

As a part of your audience analysis, you will research the specifics of your audience. This analysis will tell you important information about the demographics, disposition and knowledge of your audience. All of these factors will impact on your choice of language for your communication piece.

There are a few do's and don'ts when communicating with non-scientific audiences:

- DO use plain language
- DO NOT use scientific jargon
- DO use compelling arguments and scenarios
- DO use symbolism and analogies.

### *Avoid using scientific jargon*

Jargon is the specialised vocabulary of any profession, trade, science or hobby. Scientific jargon is that vocabulary specific to science, and each field of science will have its own jargon.

Any biochemist researching in the area of antioxidants and oxidative stress will be familiar with terms such as free radical, superoxide dismutase, catalase, glutathione peroxidase, reactive oxygen species, superoxide, hydroxyl radical, hydrogen peroxide, SOD, GPX and H2O2.

But do not use any of this jargon when communicating with non-expert audiences. Instead, you will need to replace the relevant jargon with simple words that your audience will understand:

Low levels of alpha-tochopherol promotes endothelial dysfunction.

Becomes:

An appropriate intake of vitamin E in the diet is important to maintain healthy blood vessels. (Scientific statement translated for a group of individuals who need to improve their diet to reduce the risk of cardiovascular disease.)

### *Use compelling arguments and scenarios*

Although you should never exaggerate the science when communicating with your audience, it is appropriate to tell the truth and share scenarios that may be confronting.

For example, if you are communicating with a group of smokers, it might be appropriate to show pictures of what a smokers' lung looks like. Likewise, let your audience know what their health outcome could be if they continue to smoke heavily.

Compelling arguments and scenarios are more likely to affect the audience and – as we already know – this brings potential for action and positive change.

### *Use symbolism such as analogies*

Using symbolism or analogies is not a necessity when communicating science to the public, but it may be appropriate in some circumstances.

An analogy is a comparison between one thing and another, typically to explain or clarify something.

Given that scientific concepts may be difficult for the general public to grasp, using an example of something the audience is already familiar with can help them to understand what you are trying to tell them.

In **Video 8.1** you will see the clever use of analogy and art to communicate science.

## 8.2 EXAMPLES OF COMMUNICATION PIECES FOR NON-SCIENTIFIC AUDIENCES

As you can see from the examples in this section, the ideas for communicating effectively are endless.

It might be easier than you think to create something that will have an impact on a population group and help increase the scientific literacy in our society. What are you waiting for?

Video 8.1: Michiko Maruyama and Art of Learning [2 mins, 40 secs]

Dr. Michiko Maruyama applied for medical school after surviving a rare cancer — an experience she doodled about and submitted as a comic strip for her medical school application. Now, she regularly uses art to communicate with her patients, and she dreams of opening a studio dedicated to integrating art, design and medicine. You can view Dr. Michiko's art on their website the Art of Learning.

**Note:** Closed captions are available by clicking the CC button below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=311#oembed-1

### Magazine article explaining research findings to a non-expert audience

You need to write a 500-word article for the non-expert audience explaining the pathophysiology of a disease. In addition, you include recent research findings from a published journal article: Vance, E., *Is Estrogen the New Ritalin?*, in *Scientific American Mind*. 2010, Munn & Co.: New York, NY. p. 6. Below are some new stories explaining research finding to a non-expert audience.

Box 8.5: New stories

#### News story published on a website explaining exciting new scientific inventions for studying disease and what this means for patients

**Source:** Cincinnati Children's. (2014). Lab-developed intestinal organoids form mature human tissue in mice. Available from: http://www.cincinnatichildrens.org/news/release/2014/lab-grown-intestines-10-19-2014/.

#### News story published on a website about a new potent antibiotic that doesn't encounter any detectable resistance

**Source:** Kelland, K. (2015). "Scientists discover 'game-changing' new antibiotic for first time in 30 years." Available from http://www.abc.net.au/news/2015-01-09/scientists-discover-new-antibiotic-for-first-time-in-30-years/6007730

#### News story published on a website explaining an important discovery of a genetic mutation

**Source:** Kelland, K. (2015). "Gene mutations key to heart muscle disease identified." Available from http://www.abc.net.au/science/articles/2015/01/15/4162649.htm.

#### News story published on a website announcing the trial of an Ebola vaccine

**Source:** Lapook, J. (2014). "Ebola vaccine human trials begin." Available from http://www.cbsnews.com/news/ebola-vaccine-being-tested-in-rapid-fashion-say-researchers/

### Classroom activity/lesson plan to help explain a concept to primary school students

A primary school teacher needs a lesson they can use in one a 1-hour class. You could provide a solution that

includes a few PowerPoint slides, an activity for the students to do and some questions at the end so they can test how well they did.

Example resource

The game Synaptic tag helps students learn about neuroscience.

### Classroom activity/lesson plan to help explain a concept to first-year university students studying physiology

First-year physiology students need to understand a challenging concept in an upcoming workshop. The communication activity could help students with terminology or an activity a team of students could engage in to understand the concept.

Resource

Carvalho, H. (2011). A group dynamic activity for learning the cardiac cycle and action potential. *Advances in Physiology Education,* 35(3).

### A poster displayed in a clinic waiting room to communicate ways to reduce the risk of contracting/transmitting an illness or disease

You could use your graphic design skills to design a poster that incorporates some physiology and a public health message. You could also design a brochure to give health centre patients to take home.

See some historical examples of public health posters collected by the US National Library of Medicine.

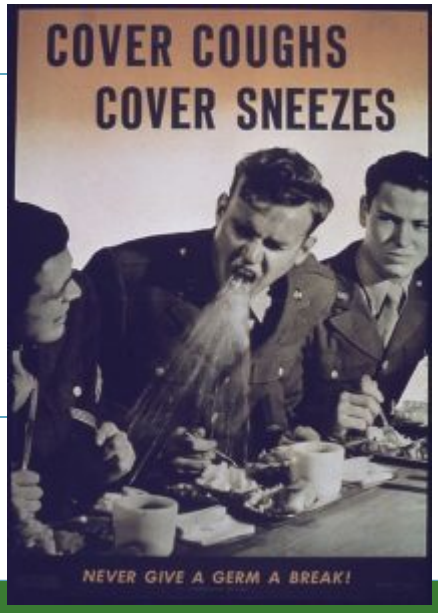


*Figure 8.3: Poster. Source: '"Cover Coughs, Cover Sneezes" – NARA – 514081' by US National Archives and Records Administration, used under CC0 1.0 licence.*

### A game for university classmates to help remember a difficult concept

You studied a challenging concept in second-year physiology, and want to design a fun game that will help students understand the physiology or to revise before an exam.

Resource

Odenweller, C., Hsu, C., & DiCarlo, S. (1998). Educational card games for understanding gastrointestinal physiology. *Advances in Physiology Educatio*n, 275(6).

### A video explaining a useful concept to non-experts

You have learned to use some video production software, and you want to use these skills to make a video (or 12–14 frame storyboard) explaining and important concept

Video resources

- Kidney physiology
- Cardiovascular system

### A song explaining a useful concept to non-experts

If you are a talented songwriter, you write a song suitable for your target audience that explains a scientific concept. Your target audience could be for primary school or university students, or for the general public – for example, a jingle for an advertising campaign.

Video 8.1: Circulatory song [3 mins, 20 secs]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=311#oembed-2

### A podcast in which you explain an important concept for a non-expert audience

You love making podcasts, so you make one about something that you find interesting and important enough to be published on your university website.

Resources

- The Infinite Monkey Cage
- 60-Second Science
- Talk Nerdy

### A mobile app for smartphones or tablets that allows students of any age to better understand a concept

You may want to design a mobile app that secondary or tertiary students can use to start understanding physiology – in a fun way!

### An artwork for display that demonstrates your understanding of a concept

If you are a talented artist, you could create an artwork (painting, mixed-media model, sculpture or a set of mounted photographs) that could be displayed in the newly refurbished physiology laboratories, or in an

appropriate setting such as a physiotherapists waiting room. The artwork explains an important concept in a creative and appealing way.

Resources

- Running
- Calcium and the pancreas

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=311#h5p-30



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CHAPTER 9

# *Your Life and Career as a Scientist*

So far, you learned 'how to do science'. But what now? Being a scientist means that science will be a part of your life for years to come.

The way a scientist thinks and behaves informs how they carry out scientific tasks. Alongside developing your scientific knowledge and skills throughout your science degree, you will be given the opportunity to develop the personal and professional responsibility that will guide you throughout your life – professionally and personally.

This chapter explains what it means to be a scientist, which is more than just 'doing science'. You'll also learn about careers options, and how to use your skills once you enter the workforce.

A group of science academics, science students, employment groups and professional societies. identified three things that a science graduate should know and be able to do regarding accountability for their own learning and scientific work by the time they graduate (Yucel, 2013). This includes:

- Being independent and self-directed learners
- Working effectively, responsibly and safely as an individual or a team
- Demonstrating knowledge of the guidelines and laws relevant to their disciplinary areas, and personally practising ethical conduct

## 9.1 BEING INDEPENDENT AND SELF-DIRECTED LEARNERS

Employers of science graduates often try to find candidates with a variety of skills such as having the ability to make decisions, being project management-minded, being resourceful and having good problem-solving abilities (Yucel, 2013).

In the workforce, science graduates often find themselves in an environment that has little direction from management, and they may need to develop or adapt new skills and understandings. Therefore, as a student scientist, learn to take responsibility for your success during your studies, so you will be prepared to continue doing so after you graduate.

To succeed in your chosen career, you will need to develop autonomy as a learner and be able to judge your own performance – **Figure 9.1** shows the characteristics you will need to become an independent and self-directed learner.

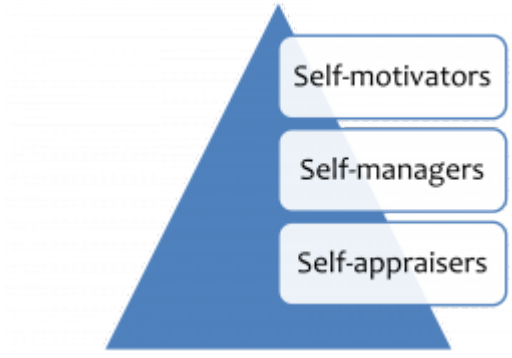


*Figure 9.1: Characteristics of an independent and self-directed learner. Source: Image by La Trobe University used under a CC-BY-NC-SA 4.0 licence.*

### Cognitive skills you need to be a good scientist

To be able to think like a scientist and conduct all of the tasks required of a scientist, you need to develop the cognitive skills lying along a continuum – from simple to complex – as shown in Bloom's taxonomy of learning (**Figure 9.2).**

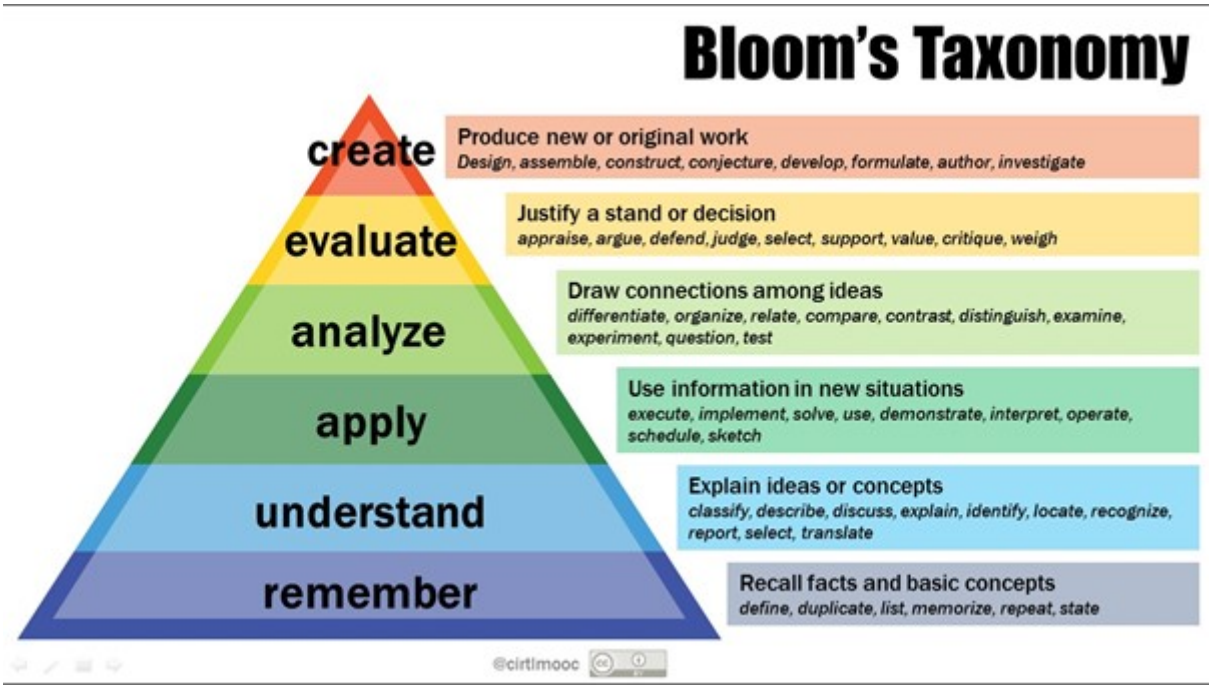


*Figure 9.2: Bloom's taxonomy of learning (Bloom, 1984).* ***Source:*** *Image by Patricia Armstrong used under CC BY 4.0 licence.*

### Capabilities and attributes required to be a scientist

> Capabilities and attributes are skills that you can demonstrate and are highly valued by employers.

Most universities have a set of skills that are referred to as 'graduate capabilities' and these are usually focused around similar skillsets. Sometimes graduate capabilities are referred to as 'generic skills' or 'transferable skills' – but most of all they can be thought of as 'interdisciplinary skills' that are important in science as well as a range of other disciplines.

Interdisciplinary skills are the foundation skills that graduates will use in their everyday work to communicate effectively, professionally, ethically, and with understanding for the diversity of the population in all occupations and disciplines (La Trobe University, 2016).

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https://usq.pressbooks.pub/howtodoscience/?p=326#h5p-31

## 9.2 WORKING EFFECTIVELY, RESPONSIBLY AND SAFELY AS AN INDIVIDUAL

## OR A TEAM

Scientists will work both independently and in teams, and will practise working in both contexts during their undergraduate degree – see below (Whatley, 2009).

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=326#h5p-33

As a student scientist, it is essential that you adopt a professional approach to your scientific learning and work because this will ultimately help you to make important contributions to science and society.

Ways in which you can adopt a professional approach include:

- demonstrate the use of appropriate techniques and equipment in projects
- be organised, on time and respectful to colleagues
- demonstrate an awareness of relevant issues such as environmental, safety, community or political issues
- seek a range of information to develop and strengthen projects that you are part of
- interact with appropriate specialists to achieve agreed outcomes and develop broader knowledge
- adapt positively to change and take initiative
- complete tasks in a safe, competent and timely manner
- demonstrate professional ethics

Student scientists should conduct scientific enquiry in a manner that falls within the codes of practice for workplace health and safety. This includes considering the following when relevant:

- basic workplace health and safety
- biological safety
- chemical safety
- electrical safety
- laboratory equipment safety
- personal protective equipment
- radiation and laser safety

*Figure 9.3: 'Researchers review documents' by Rhoda Baer, used under CC0 1.0 licence.*

### Team context

All scientists work in teams, and student scientists will get to practise their team work skills during their undergraduate degree. Some features of successful teams are shown in **Figure 9.4.**

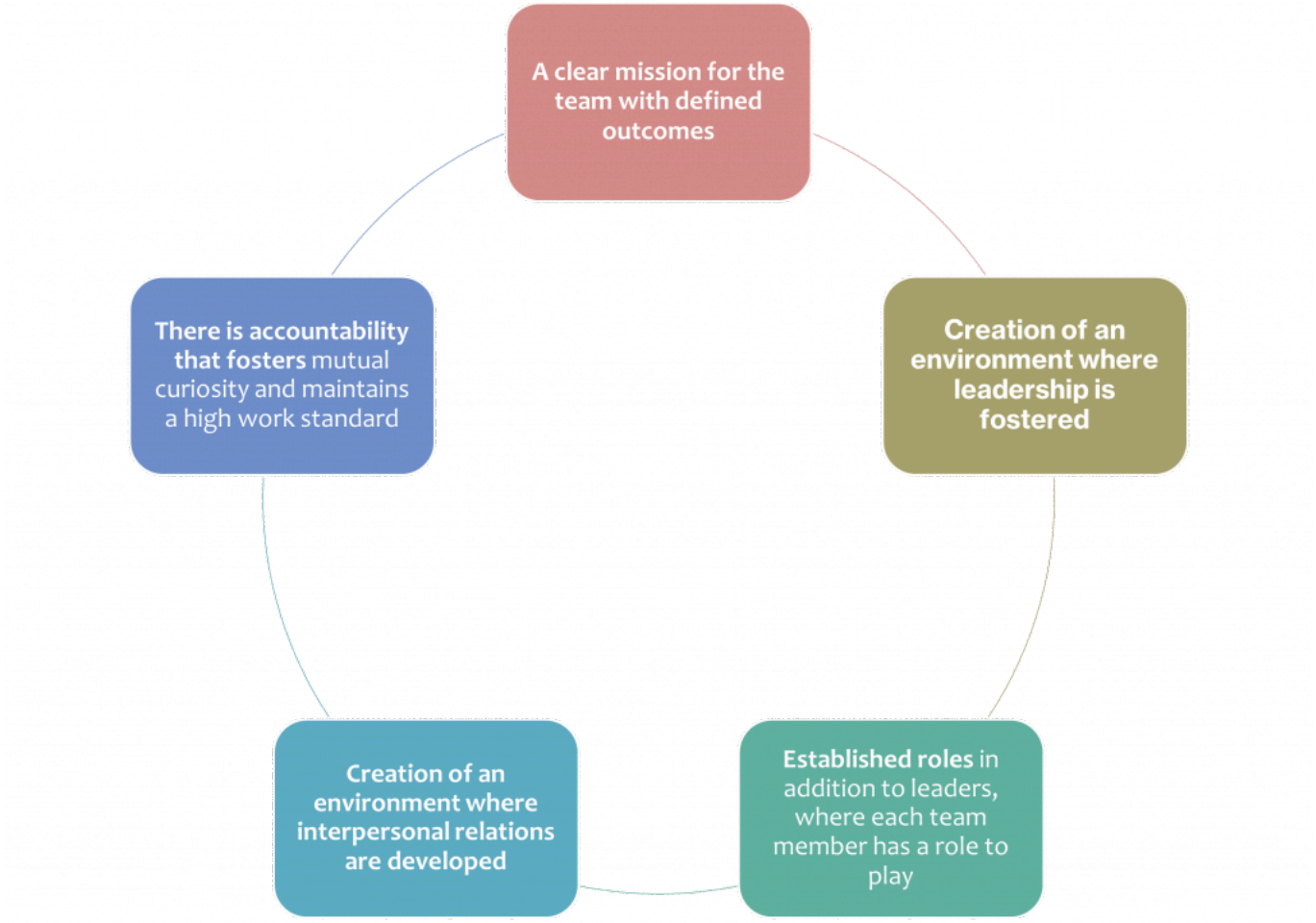


*Figure 9.4: Features of successful teams.* ***Source:*** *Adapted and reproduced with permission from Whatley, J. (2009). Ground rules in team projects: Findings from a prototype system to support students. Journal of Information Technology Education, 8, 161-176. https://doi.org/10.28945/165.*

## Teams are formed when people come together to work towards a common goal

Resource

Read about how you can be an effective and efficient team member in this Good Practice Guide [PDF].

### Team projects

There are several things you should consider when starting a team project:

- Get to know the rest of your team. *Think of your team as puzzle pieces that can be placed together in a variety of ways* (Llopis, 2012).
- Establish team work agreements. Newly established teams should consider completing a team work agreement. It has been shown that team cohesion, trust, and awareness of members' obligations, expectations of others and working relationships are improved when teams establish ground rules at the beginning of a project (Whatley, 2009).
- Create team goals. Decide on the big-picture goals of the team and record these (perhaps in your

team agreement).

- Create task lists, and **clearly define roles and responsibilities.** *A team should operate as a mosaic whose unique strengths and differences convert into a powerful united force* (Llopis, 2012). Create a detailed task list and a time line for completion of these tasks.
- Decide on a team communication process. This includes the preferred method, frequency and nature of team communication, and ensure relevant contact details are shared. Consider making use of tools that let you communicate and collaborate with your team mates online. For example, use Zoom software for online video meetings when you can't meet in person. Office365 and Google software allow multiple people to work together on one document, spreadsheet or presentation.
- Establish proper team dynamics. Decide on acceptable and unacceptable team dynamics, and record how unacceptable team dynamics will be dealt with should they arise (perhaps in your team agreement).

Box 9.1: Effective ways to communicate with your team

Here some effective ways to communicate with your team – compiled from past student scientists.

- Share phone numbers and email addresses
- Reply to team members in a timely fashion
- Arrive at team meetings and class on time
- Use social media to communicate
- Complete necessary and appropriate prereading
- Set small, achievable deadlines frequently
- Have a team brief at the beginning of team sessions
- Use time wisely

## 9.3 GUIDELINES, LAWS AND ETHICAL CONDUCT

High-quality science graduates have an understanding of their social, cultural and environmental responsibilities as they study the natural world.

As a student scientist, you should do your best to behave ethically throughout your undergraduate study, to prepare you to become an ethical professional. Examples of ethical conduct in action include:

- accurate data recording and storage
- proper referencing and avoiding plagiarism
- intellectual integrity
- safely disposing of biological and chemical waste
- knowledge and application of the principles of animal ethics and/or human ethics.

Being an ethical scientist is more than just doing the right thing. It requires scientists to act in the right spirit, out of respect and concern for one's fellow creatures (National Health and Medical Research Council et al., 2015).

## How to be an ethical scientist – personal responsibility

Scientists and philosophers have spent their lives considering the aims of science and how scientific research should be conducted. Haque et al. summarised the most important principles displayed by an ethical scientist (Hasque et al., 2022).

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=326#h5p-37

## How to be an ethical scientist – guidelines and laws

In many cases, the government may be involved in establishing guidelines or laws for safe and ethical behaviour.

Guidelines are sets of non-mandatory rules, principles or recommendations for procedures or practices in a particular field. Laws are rules that regulate the actions of people and may be enforced by applying penalties.

There are guidelines and laws relevant to scientists that cover experimentation and data collection, quality control procedures and appropriate safety procedures. There are also instances when you might need to obtain a government permit for a certain type of activity or research. For example, scientists and student scientists need to perform scientific work in accordance with the *Workplace Health and Safety Act 2011*. This act provides a balanced and nationally consistent structure to help protect workers, including science students, against harm to their health, safety and welfare by eliminating or minimising work-related risks.

### *Human research*

Scientists and science students involved in human research studies need to respect human research participants. They also need to comply with ethical principles of integrity, respect for persons, justice and goodness, as elaborated in the *National Statement on Ethical Conduct in Human* Research.

The statement is a series of guidelines developed by the National Health and Medical Research Council, the Australian Research Council and Universities Australia. These guidelines were developed to promote ethically good human research, protect participants and foster research that will benefit the community.

Unfortunately, history shows us that human research participants have not always been treated with respect. Some research studies have been done in the past that humanity should not be proud of.

Video 9.1: The worst Nobel Prize ever awarded [9 mins, 26 secs]

**Note:** Closed captions are available by clicking on the CC button below.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://usq.pressbooks.pub/howtodoscience/?p=326#oembed-1

Resource

Take a look at this comprehensive research ethics timeline from 1932 to the present.

Case study 9.1: Ethics of stem cell research

Most of us have heard of stem cell research, but what exactly is it?

Stem cell research involves using embryonic stem cells or adult stem cells to learn more about human health and disease. Embryonic stem cells are derived from embryos and are highly versatile –they can give rise to any type of cell in the fully developed body. Adult stem cells are more limited, because they can only give rise to certain cells types.

Australian scientists have been at the cutting edge of stem cell research since the discovery of the human embryonic stem cell line in the late 1990s. Despite the overwhelming potential of this research to progress human health, some individuals are highly opposed to the use of embryonic stem cells because of the associated ethical issues.

There has been much debate around the ethical issues associated with stem cell research. The following videos show both US President Bush's and Obama's view of this research.

As you will see, world leaders don't always agree on the ethical issues surrounding modern day scientific research:

- George W Bush on Stem Cell Research
- President Obama on Stem Cell Research

### *Animal research*

To learn more about human health and disease, many scientists use animal models. When doing so, the welfare of the animals must be respected.

The *Australian Code of Practice for the care and use of animals for scientific purposes 8th edition* (2013) provides principles for the guidance of teachers, investigators, and all people involved in the care and use of animals for scientific purposes. It provides guidelines for the humane conduct of scientific and teaching activities, and for accessing animals.

The code of practice states that animals should only be used for scientific purposes when the study:

- has scientific or educational merit
- aims to benefit humans, animals or the environment
- is conducted with integrity.

In addition, the number of animals used should be minimised, the wellbeing of the animals must be supported, and harm (including pain and distress) in the animals must be avoided or minimised.

Nevertheless, the community still debates as to whether animals should be used to progress science. The following videos present both sides of this debate:

Resources

- Animal Research Laboratory
- Animal Testing Ethics
- Taboos of Science

## 9.4 CAREERS FOR SCIENCE GRADUATES

> The great physicist Edwin Hubble, speaking at Caltech's commencement in 1938, said a scientist has 'a healthy skepticism, suspended judgement, and disciplined imagination' – not only about other people's ideas but also about his or her own. The scientist has an experimental mind, not a litigious one (Gawande, 2016).

Student scientists don't necessarily go on to a career as a laboratory-based scientist. They do, however, take their scientific literacy and skills to whatever profession they enter. Trained scientists are valuable additions to teams and companies from a range of disciplines and fields.

Australia's former Chief Scientist Professor Ian Chubb and his office prepared a report on the importance of science, technology, engineering and mathematics (STEM) graduates in Australia's future, which stated:

> An education in STEM ... fosters a range of generic and quantitative skills and ways of thinking that enable individuals to see and grasp opportunities. These capabilities – including deep knowledge of a subject, creativity, problem solving, critical thinking and communication skills – are relevant to an increasingly wide range of occupations. They will be part of the foundation of adaptive and nimble workplaces of the future (Office of the Chief Scientist, 2014, p. 7)

Throughout your undergraduate degree, you will develop a range of practical skills that will be useful in whatever professional roles you take on in the future, including:

- How to work in a laboratory
- How to reference
- How to do statistical analyses
- How to search databases
- How to talk and write about science and other topics
- How to work as part of a team
- How to present data in, for example, graphs or tables

The United Kingdom's Science Council has identified 10 types of scientists working today (Science Council, 2016). This list highlights the fact that not all scientists end up working in laboratories – in fact, there are a wide variety of jobs that need the knowledge and skills developed during a science degree, as discussed earlier in this chapter.

Click the drop down below to review the terms learned from this chapter.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://usq.pressbooks.pub/howtodoscience/?p=326#h5p-36



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# *Glossary*

**Abstract:** A paragraph of 200 to 300 words that accurately reflects the contents of a research article or literature review.

**Adaptability:** The ability to change positively and with ease to fit changed circumstances.

**Aim:** The goal or objective of a scientific research study; to determine the effect of the independent variable(s) on the dependent variable(s). Appears in an abstract or introduction of an original investigation.

**Analysis:** The ability to take a process or thing and break it down into its basic parts and draw connections.

**Analysis grid:** A tool that helps with the careful examination and breakdown of a research paper.

**Analysis of variance (ANOVA):** A statistical procedure used to test the degree to which the dependent variable values for 3 or more groups differ in an experiment. Apply To use information in new situations.

**Author–date reference system:** A type of referencing system where in-text citations are indicated by placing the author's surname and the date of publication in brackets, and the reference list is in alphabetical order by author's surname.

**Balanced groups:** Different experimental groups with no obvious differences.

**Baseline measurements:** Dependent variables measured at the beginning of an experiment; generated to balance groups or to compare with the same dependent variables measured throughout or at the end of the experiment.

**Bibliography:** A list at the end of a book or article that shows the works used by the author in writing the article or book, or a list of works that a reader might find useful.

**Citation:** A reference to a book, paper or author, especially in an academic work.

**Column graph:** A figure that uses bar shapes to plot the mean values.

**Communication platform:** The mode of communicating information, such as podcast, video, brochure, poster or book.

**Conclusion:** The answer to your research question; it summarises how the results of a scientific study support or fail to support the hypothesis. Appears at the end of the discussion section of a research article.

**Control group:** A group of animals or humans that receive experimental conditions identical to that of the treatment group (eg for animals' diet and housing conditions), except for the independent variable(s) of interest.

**Control group experimental design:** Experimental design in which the participants are divided into two groups, one of which is designated the control and the other the experimental group.

**Correlation:** A statistical approach to determine how well two variables are related to each other.

**Create:** To produce new or original work.

**Critical analysis:** An examination and evaluation of a text or other work that may help us to understand the interaction of the particular components that contribute to the value of the work; it is not a quest to find fault with the work.

**Critical thinking:** The analysis and evaluation of an issue that is based on sound logic.

**Crossover experimental design:** Each participant is measured under the control and experimental treatment conditions, with one-half of the participants experiencing the conditions in reverse order.

**Cultural literacy:** The ability to understand and participate fluently in a given culture; citizens share a common body of knowledge that allows the building of positive communication, acceptance and understanding in a changing world.

**Demographic analysis:** Determination of the age, sex and racial composition of a population.

**Dependent variable:** The variable (or variables) that changes in an experiment as a result of the independent variable.

**Descriptive statistics:** A quantitative summary of features of a dataset; includes mean and standard deviation.

**Discipline-specific knowledge and skills:** Capabilities specific to the field of study (eg human physiology), but not covered by other more generic capabilities such as literacies and communication skills, personal and professional skills, and inquiry and analytical skills.

**Disposition analysis:** Determination of the usual attitude or mood of a particular group of people, their tendency to act or think in a particular way, as well as their needs, goals and interests.

**Double-blind study:** Study in which the individual participants and the people administering the experiment are unaware of critical aspects of the experiment, with this information being held by a third party and only revealed to the investigators when the study is completed.

**Employability:** A set of achievements, understandings and personal attributes that make individuals more likely to gain employment and to be successful in their chosen occupations.

**EndNote:** A software package used to manage bibliographies and references when writing scientific papers.

**Error bars:** Graphical representation of the variability of data around the mean (eg standard deviation).

**Evaluate:** To critique and appraise information to come to a conclusion, and to defend the conclusion.

**Evidence:** Data or information on which to base proof, or to establish truth or falsehood.

**Experiment:** A test conducted under controlled conditions to test a hypothesis.

**Experimental design:** A research design that eliminates all factors that influence outcome except for the variable being studied.

**Extraneous variable:** An unwanted variable that is not the independent variable of interest, but influences the outcome of an experiment, and therefore adds error to an experiment.

**General public:** People in society; used when contrasting people in general with a small group – for example, scientists.

**Generic skills:** Important in science and other fields, and often referred to as graduate capabilities. They can include literacies and communication skills, inquiry and analytical skills, personal and professional skills, and discipline-specific knowledge and skills.

**Google Scholar:** An online, freely accessible search engine used to search for scholarly literature across a range of publishing formats and disciplines.

**Graduate capabilities**: Generic skills that are important in science. They can include literacies and communication skills, inquiry and analytical skills, personal and professional skills, and discipline-specific knowledge and skills.

**Guideline:** A general rule, principle or piece of advice designed to streamline particular processes according to a set routine or sound practice, and, by definition, not mandatory.

**Human physiology:** The science of the mechanical, physical and biochemical functions of normal humans, or human tissues or organs, primarily at the level of organs and systems.

**Hypothesis:** An assumption or prediction based on sound evidence (educated guess) assumed for the sake of testing its soundness; a prediction of the effect of the independent variable(s) on the dependent variable(s) in a scientific research study.

**Independent learning:** When an individual executes autonomy over their learning and evaluates their own learning.

**Independent t-test:** A statistical test to determine whether there is a statistically significant difference between the means in two unrelated groups.

**Independent variable:** The variable that the investigator intentionally changes in a scientific experiment to observe its effect on other variables.

**Inquiry and analytical skills:** Capabilities around critical thinking, creative problem solving, inquiry and research.

**In-text-citation:** A reference placed immediately after the information being cited, which helps readers easily reconcile the information and the source.

**Introduction:** The section of an original investigation research article that provides a brief literature review that encapsulates the rationale for the study, as well as the hypotheses and aims.

**Investigator:** A researcher or scientist who implements the scientific method to generate new scientific knowledge.

**Knowledge analysis:** Determination of the knowledge base on a given topic area in a given cohort of people.

**Laws:** A rule established by some authority and enforced by judicial decision.

**Line graph:** A figure that plots the mean values and connects the points with a line to show something that happens over time.

**Literacies and communication skills:** Capabilities around writing, speaking, quantitative literacy and cultural literacy.

**Literature review:** An academic paper that is an assessment of a body of research on a particular topic; they are secondary sources and don't report on original investigations.

**Mean:** Gives a very good idea about the central tendency of the data being collected; determined by adding all the data points in a dataset and then dividing the total by the number of points.

**Methods:** The section of a research article that explains how the original investigation was done.

**Number reference system:** A type of referencing system where a source is cited in the text using the number assigned to that source in the reference list.

**Observation:** The active acquisition of information from a primary source, either through our senses, or data recorded during an experiment using scientific tools and instruments.

**One-factor analysis of variance (ANOVA):** A statistical procedure used to test the degree to which the dependent variable values for 3 or more groups differ in an experiment where there is 1 independent variable.

**Original investigation research article:** Published account of a new study undertaken on a particular topic.

**Paired t-test:** A statistical test to determine whether there is a statistically significant difference between the means in two groups each containing the same subjects.

**Participant:** An individual who participates in a research study as a human subject and is the target of observation by researchers.

**Peer review:** A process by which scholarly work is checked by a group of experts in the same field to make sure it meets the necessary standards before it is published or accepted.

**Personal and professional skills:** Capabilities around teamwork, leadership, autonomy and independence, ethical behaviour, adaptability, and study and learning skills.

**Physiology:** The branch of biology that deals with the normal functions of living organisms and their parts.

**Placebo:** A dummy medication that has no therapeutic effect given to the control group in a study that is investigating the effect of a medication on relevant physiological variables.

**Post hoc test:** A stepwise multiple comparisons procedure used to identify sample means that are significantly different from each other when a significant difference between 3 or more sample means has been determined by an analysis of variance (ANOVA).

**Problem solving:** The process of finding solutions to difficult or complex issues.

**Pseudoscience:** A form of science without substance; a claim, belief or practice presented as scientific but doesn't adhere to the scientific method.

**PubMed:** An online, freely accessible search engine for accessing primarily the MEDLINE database of references and abstracts on life sciences and biomedical topics.

**p value:** A statistical value that helps you to determine the significance of your results; a conventional (and arbitrary) threshold is a value of less than 0.05.

**Quantitative literacy:** The ability to understand and interpret numerical information, and the ability to apply mathematical skills when solving real-world problems.

**Random assignment:** An experimental technique used where human participants or animal subjects are arbitrarily assigned to different groups in an experiment, because the experimenters are confident that this will result in balanced groups.

**Reference:** The use of a source of information to ascertain something.

**Reference list:** A list of all the sources used as intext references in a scientific paper that enables the reader of the work to locate and verify the sources used.

**Referencing style:** The particular format of a reference that is used throughout the reference list for consistency.

**Reliable evidence:** Stable and consistent data generated from an assessment tool.

**Remember:** To recall facts and basic concepts.

**Results:** The findings of an original research investigation.

**Science:** The pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence.

**Science literacy:** The knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.

**Scientific figure:** A standalone and interpretable graphic representation of scientific research findings that plots descriptive statistics and has significance symbols, labelled x and y axes with units, and a caption.

**Scientific figure caption:** Conveys relevant information about a graphic representation of scientific research findings; appears below the graph and includes a descriptive title, the summary statistics that have been plotted, and a statement
as to whether or not there is a statistical difference between results.

**Scientific literature:** The aggregate of scholarly publications written to inform on the latest achievements of science, and within an academic field; includes primary, secondary, tertiary and grey literature.

**Scientific method:** A method of procedure consisting of systematic observation, and the formulation, testing and modification of hypotheses.

**Scientific table:** A standalone and interpretable tabular representation of scientific research findings that has summary statistics presented as numerical data, significance symbols and a caption.

**Scientific table caption:** Conveys relevant information about a tabular representation of scientific research findings, appears above the table and includes a descriptive title, the descriptive statistics presented, and a statement as to whether or not there is a statistical difference between results.

**Scientific theory:** A conceptual scheme supported by a large number of observations and not yet found lacking.

**Scientific units:** A standard of measurement (eg metre, kilogram) used to quantify variables. Some well-known variables and their standard of measurement in physiology are heart rate (beats per minute), mean arterial pressure (mmHg), blood
glucose (millimoles per litre) and ventilation (litres per minute).

**Scientist:** An expert in one or more areas of science who creates knowledge via systematic activity or implementation of the scientific method, and shares this information with other experts in the field.

**Secondary literature:** Publications that rely on primary sources for information, and where it is not a requirement for the authors to have done the work themselves, since the purpose of the publication is to summarise and synthesise knowledge in a specific area for other scientists who already have an understanding of the topic.

**Self-directed learning:** When an individual executes autonomy over their learning and evaluates their own learning.

**Significance symbol:** A character used in a scientific figure or table to represent statistical difference between datasets.

**Single-blind study:** Experiment in which the individual participants do not know whether they are are control or treatment group participants.

**Standard deviation:** A measure of the dispersion of a set of data from its mean.

**Statistical analysis:** The science that deals with the collection, analysis and interpretation of numerical data.

**Statistical significance:** A result from testing or experimentation that is not likely to occur randomly or by chance, but is instead likely to be attributable to a specific cause; a conventional (and arbitrary) threshold for declaring this is a
p value of less than 0.05.

**Statistics:** The science that deals with the collection, analysis and interpretation of numerical data.

**Student scientist:** An individual who is undergoing formal education where they are learning about science and how to practise science, as well as developing scientific skills and attributes such as teamwork, communication, and personal and
professional responsibility.

**Summary synthesis:** The ability to combine discrete pieces of information into a number of whole parts, and then summarise the whole parts and draw connections between them.

**Synthesise:** To combine discrete pieces of information into a whole.

**Synthesis grid:** A tool that helps with the amalgamation of findings from separate original investigations.

**Team:** A group of people with a full set of complementary skills who work together to achieve a common goal.

**Teamwork:** The combined efforts and actions of a group of people working together to achieve a common goal.

**Transferable skills:** Important in science and other fields, and often referred to as graduate capabilities. They can include literacies and communication skills, inquiry and analytical skills, personal and professional skills, and discipline-specific knowledge.

**Treatment group:** The experimental group that is exposed to the independent variable(s) of interest.

**Treatment order control experimental design:** Experimental design in which each participant is measured under the control and experimental treatment conditions, with one-half of the participants experiencing the conditions in reverse order.

**Two-factor analysis of variance (ANOVA):** A statistical procedure used to test the degree to which the dependent variable values for 3 or more groups differ in an experiment where there are 2 independent variables.

**Two-tailed statistical test:** A test of significance to determine if there is a relationship between variables in either direction.

**Understand:** To comprehend ideas or concepts.

**Valid evidence:** Data generated during an experiment that have a sound, factual basis.

**X axis:** The line on a graph that runs horizontally (left–right) through zero.

**X-axis title:** The title for data presented on the x axis.

**Y axis:** The line on a graph that runs vertically (up–down) through zero.

**Y-axis title:** The title for data presented on the y axis.

# *Accessibility Assessment*

Below is a short accessibility assessment of eight key areas that have been assessed during the production process of this text. The checklist has been drawn from the BCcampus Open Education Accessibility Toolkit. While a checklist such as this is just one part of a holistic approach to accessibility, it is one way to begin our work on embedded good accessibility practices in the books we support.

It is our hope that by being transparent on our current books, we can begin the process of making sure accessibility is top of mind for all authors, adopters, students and contributors of all kinds on all our open textbook projects. As such, we welcome any feedback from students, instructors or others who encounter the book and identify an issue that needs resolving.

## ACCESSIBILITY CHECKLIST

| Category | Item | Status |
|---|---|---|
| **Organising Content** | Content is organised under headings and subheadings | X |
| **Organising Content** | Headings and subheadings are used sequentially (e.g. Heading 1, Heading 2, etc.) | X |
| **Images** | Images that convey information include Alternative Text (alt-text) descriptions of the image's content or function | X |
| **Images** | Graphs, charts, and maps also include contextual or supporting details in the text surrounding the image | X |
| **Images** | Images, diagrams, or charts do not rely only on colour to convey important information | X |
| **Images** | Images that are purely decorative contain empty alternative text descriptions. (Descriptive text is unnecessary if the image doesn't convey contextual content information) | X |
| **Tables** | Tables include column headers, and row headers where appropriate | X |
| **Tables** | Tables include a title or caption | X |
| **Tables** | Tables do not have merged or split cells | X |
| **Tables** | Tables have adequate cell padding | X |
| **Weblinks** | The weblink is meaningful in context, and does not use generic text such as "click here" or "read more" | X |
| **Weblinks** | Externals weblinks open in a new tab. Internal weblink do not open in a new tab. | X |
| **Weblinks** | If a link will open or download a file (like a PDF or Excel file), a textual reference is included in the link information (e.g. '[PDF]'). | X |
| **Embedded Multimedia** | A transcript has been made available for a multimedia resource that includes audio narration or instruction | – |
| **Embedded Multimedia** | Captions of all speech content and relevant non-speech content are included in the multimedia resource that includes audio synchronized with a video presentation | All videos, except one third-party video has closed captions |
| **Embedded Multimedia** | Audio descriptions of contextual visuals (graphs, charts, etc.) are included in the multimedia resource | – |
| **Formulas** | Formulas have been created using MathML | – |
| **Formulas** | Formulas are images with alternative text descriptions, if MathML is not an option | – |
| **Font Size** | Font size is 12 point or higher for body text | X |
| **Font Size** | Font size is 9 point for footnotes or endnotes | – |
| **Font Size** | Font size can be zoomed to 200% | X |