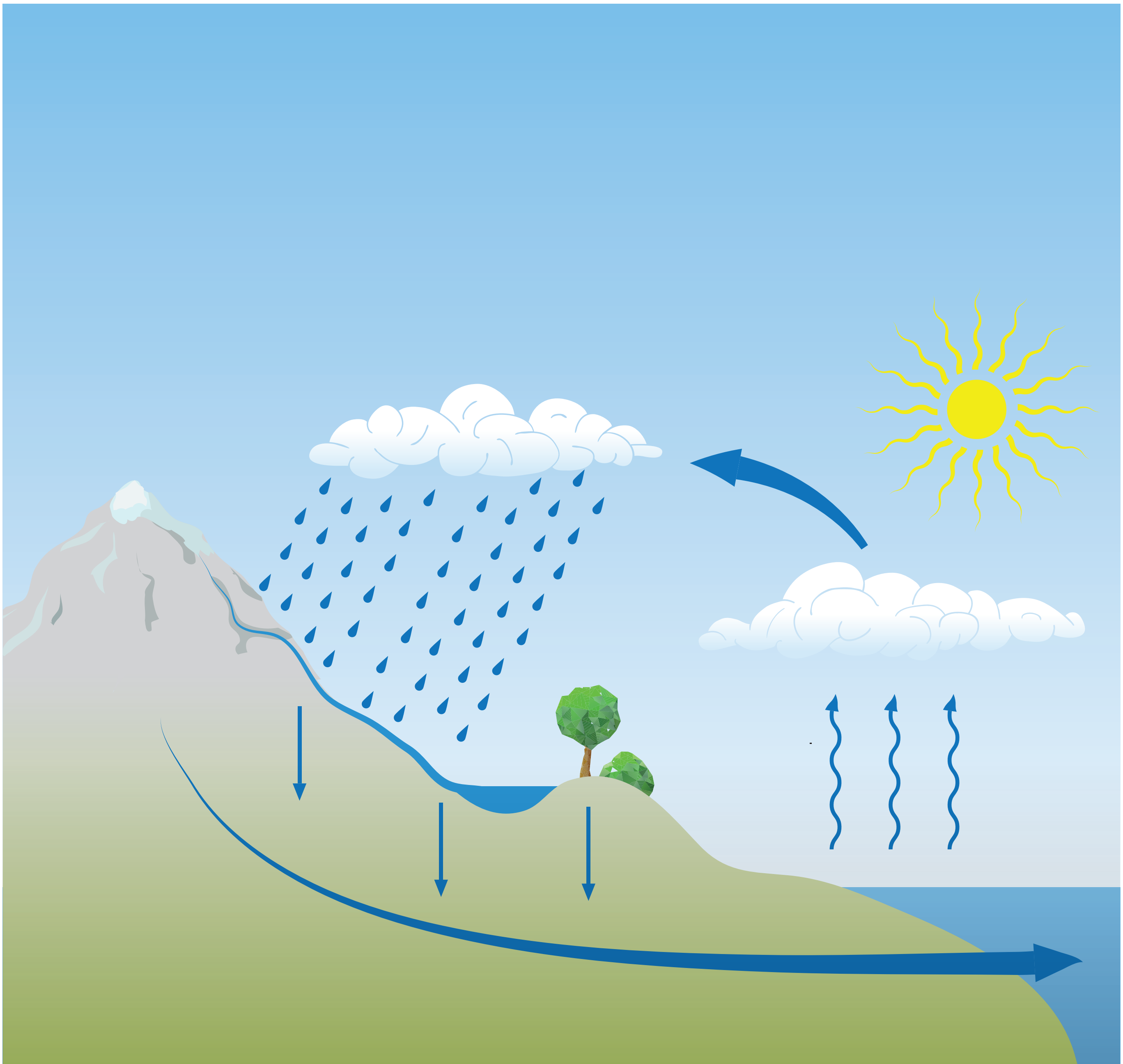


Changing Climates, Changing Waters

YEAR 7-10
EARTH AND SPACE SCIENCES
DESIGN AND TECHNOLOGIES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK | Queensland Government

Future Makers

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC business aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

This teacher resource is produced by Future Makers, a partnership between Queensland Museum Network and Shell's QGC business, with support from the Australian Research Council and other parties to ARC Linkage Project LP160101374: The University of Queensland, Australian Catholic University Limited and Queensland Department of Education.

EXPLAIN – ELABORATE – EVALUATE

Changing Climates, Changing Waters

Teacher Resource

"Climate change is no longer a threat in the distant future. It is here now and we need to adapt to the challenges it brings."[1]

There is no doubt that our climate is changing. We are observing an increase in global air and ocean temperatures, rising global sea levels, more frequent and intense extreme weather events, and changing rainfall patterns. The impacts of climate change pose significant risks to human and natural systems. It is now becoming critical to devise and implement measures that will help manage and reduce risks associated with the adverse effects of a changing climate; this is occurring at a global, national and state level.

Museums, including Queensland Museum, also recognise the role they play in addressing the impacts of climate change on biodiversity. Queensland Museum is committed to investigating how species are being affected by changing climates, providing conservation advice based on scientific expertise, research and data, and increasing public engagement and awareness of climate change.

In this activity, students apply their knowledge and understanding of the water cycle to a new context: climate change.

Climate change is influencing when, where and how much precipitation falls across the globe; some regions are becoming wetter, while other regions are becoming drier. Warming air and sea surface temperatures are increasing the rate of evaporation from the land and oceans. This, coupled with a warming atmosphere that can hold more water vapour, is resulting in more frequent and intense precipitation events[2]. An increased risk of flooding is also associated with a changing water cycle. More frequent and intense rainfall may overwhelm a catchment's ability to absorb water, resulting in increased runoff that may culminate in a flooding event[3]. Increased runoff can also threaten the health of our waterways, with excess sediment, nutrients and contaminants affecting water quality and biodiversity. In contrast, other regions are likely to experience worsening drought conditions, where an increase in air temperature, more frequent hot days and a decline in rainfall will exacerbate water loss from plants and soil[4]. These conditions pose significant risks to biodiversity, ecosystems, human health, urban water supplies, infrastructure, and industry and business.

In this activity, students adopt the role of climate scientists. They will work in groups of three to:

- Determine how climate change will affect the water cycle.
- Identify the likely impacts of these changes.
- Develop a designed solution that will minimise the impacts of these changes.

You may ask your students to conduct online research to assist the completion of this activity.

1 Kammila, S. (2019). Forward-thinking adaptation. Retrieved from https://www.adaptation-undp.org/forward-thinking-adaptation
2 The Climate Council of Australia. (2018). Deluge and drought: Australia's water security in a changing climate. Retrieved from https://www.climatecouncil.org.au/resources/water-security-report/
3 Gray, E., & Merzdorf, J. (2019). Earth's freshwater future: Extremes of flood and drought. Retrieved from https://climate.nasa.gov/news/2881/earths-freshwater-future-extremes-of-flood-and-drought/
4 CSIRO & BoM. (2016). Climate change in Australia: Projections technical report. Retrieved from https://www.climatechangeinaustralia.gov.au/en/communication-resources/reports/

Curriculum Links

Science

YEAR 7

Science Understanding

Some of Earth's resources are renewable, including water that cycles through the environment, but others are non-renewable (ACSSU116)

Science as a Human Endeavour

Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available (ACSHE119)

Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120)

Science Inquiry Skills

Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)

Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions based on evidence (ACSIS130)

Communicate ideas, findings and evidence based solutions to problems using scientific language, and representations, using digital technologies as appropriate (ACSIS133)

Design and Technologies

YEAR 7 & 8

Design and Technologies: Knowledge and Understanding

Investigate the ways in which products, services and environments evolve locally, regionally and globally and how competing factors including social, ethical and sustainability considerations are prioritised in the development of technologies and designed solutions for preferred futures (ACTDEK029)

Analyse ways to produce designed solutions through selecting and combining characteristics and properties of materials, systems, components, tools and equipment (ACTDEK034)

Design and Technologies: Processes and Production Skills

Critique needs or opportunities for designing and investigate, analyse and select from a range of materials, components, tools, equipment and processes to develop design ideas (ACTDEP035)

Generate, develop, test and communicate design ideas, plans and processes for various audiences using appropriate technical terms and technologies including graphical representation techniques (ACTDEP036)

Select and justify choices of materials, components, tools, equipment and techniques to effectively and safely make designed solutions (ACTDEP037)

Independently develop criteria for success to evaluate design ideas, processes and solutions and their sustainability (ACTDEP038)

YEAR 9 & 10

Design and Technologies: Knowledge and Understanding

Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved (ACTDEK040)

Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions (ACTDEK041)

Investigate and make judgements on how the characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions (ACTDEK046)

Design and Technologies: Processes and Production Skills

Critique needs or opportunities to develop design briefs and investigate and select an increasingly sophisticated range of materials, systems, components, tools and equipment to develop design ideas (ACTDEP048)

Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication (ACTDEP049)

Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions (ACTDEP050)

Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability (ACTDEP051)

Geography

YEAR 7

Geographical Knowledge and Understanding

The way that flows of water connects places as it moves through the environment and the way this affects places (ACHGK038)

Geographical Inquiry and Skills

Present findings, arguments and ideas in a range of communication forms selected to suit a particular audience and purpose; using geographical terminology and digital technologies as appropriate (ACHGS053)

Curriculum Links

General Capabilities

Literacy

Comprehending texts through listening, reading and viewing

Composing texts through speaking, writing and creating

Word knowledge

Information and Communication Technology

Investigating with ICT

Creating with ICT

Critical and Creative Thinking

Inquiring – Identifying, exploring and organising information and ideas

Generating ideas, possibilities and actions

Analysing, synthesising and evaluating reasoning and procedures

Cross Curriculum Priorities

Sustainability

The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future. (OI.6)

Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments. (OI.7)

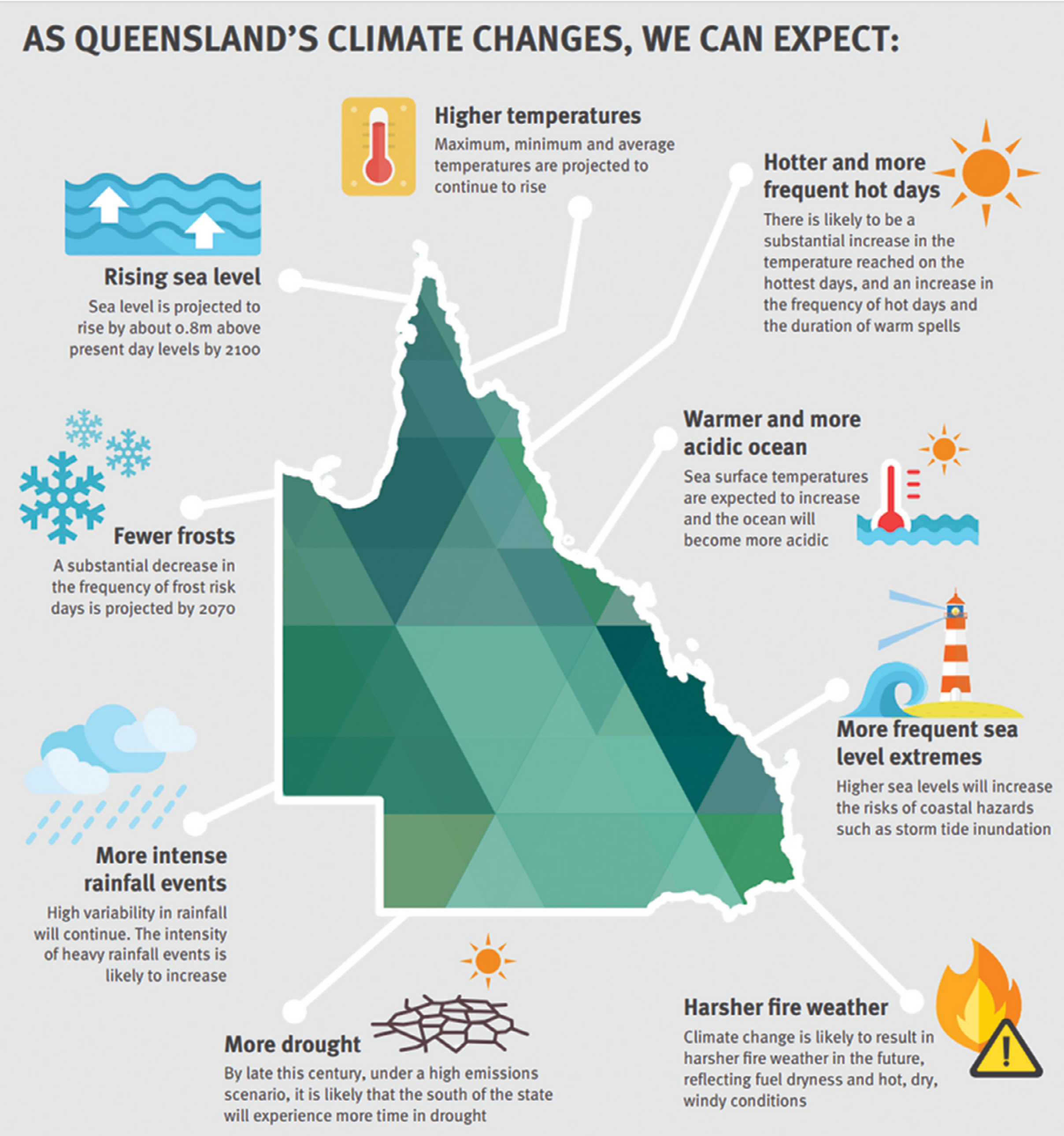
Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgements based on projected future economic, social and environmental impacts. (OI.8)

Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments. (OI.9)

Changing Climates, Changing Waters

Student Activity

One of the biggest environmental challenges to face Queensland (and the world) is climate change. Human societies and natural environments are already experiencing its impacts. Amongst other changes, we are observing higher temperatures, hotter and more frequent hot days, warmer and more acidic oceans, rising sea levels, harsher fire weather and more drought. These changes are expected to continue and intensify in the future if greenhouse gas emissions are not reduced.



How Queensland's environment is predicted to change with climate change. Image: The State of Queensland 2017.

Our changing climate is also affecting how water cycles through the environment, influencing both water quantity (too little and too much) and water quality.

Taking Action: Designing Solutions

You are a climate scientist, specialising in the impact of climate change on the availability of water. The State Government has asked you and two of your colleagues, who are also climate scientists, to provide advice on how climate change will affect the water cycle and how we can best protect our ecosystems and communities from these changes.

In order to respond to the government's request, you must:

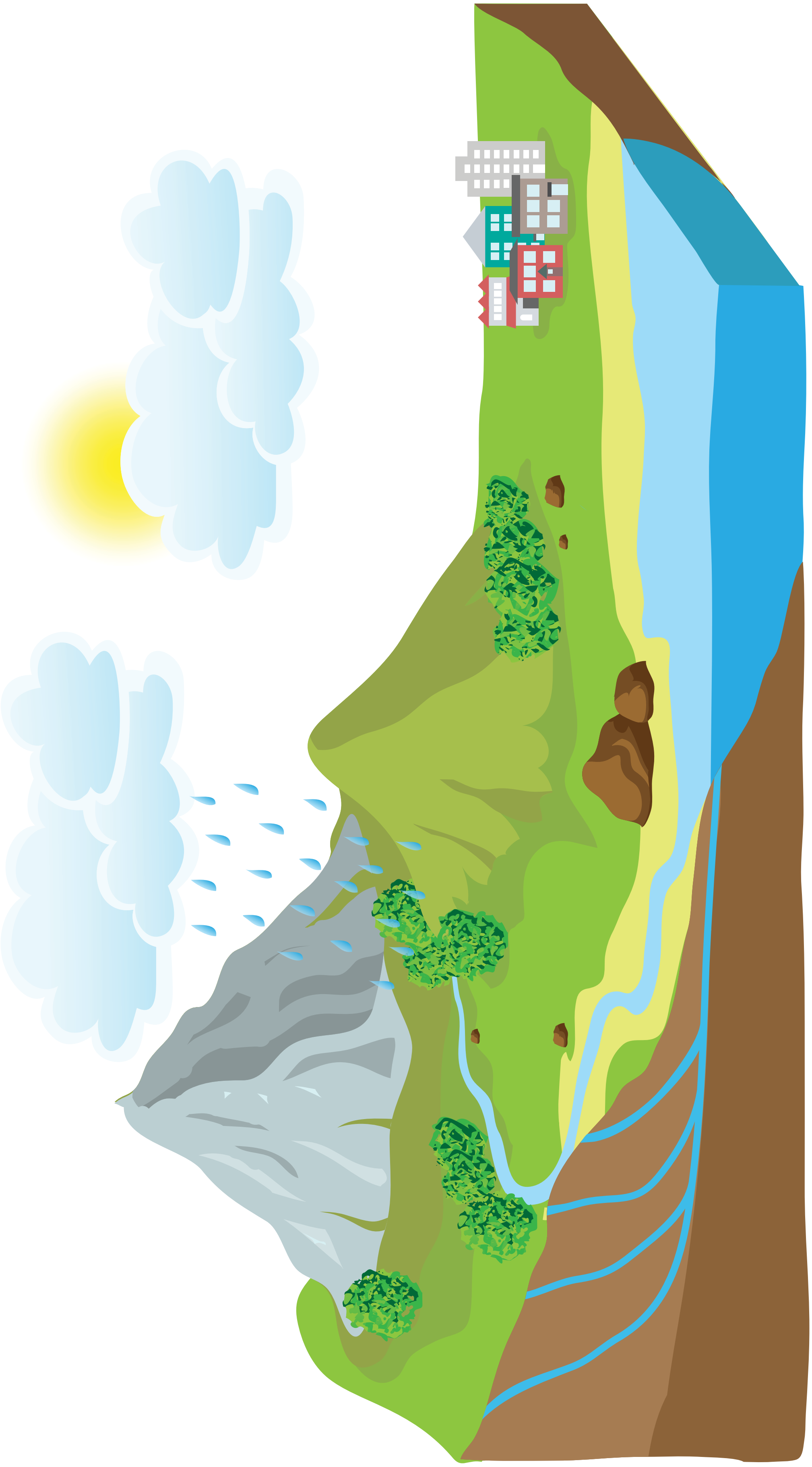
- Determine how climate change will affect the water cycle;
- Identify the likely impacts of these changes; and,
- Develop a designed solution that will minimise the impacts of these changes.

Part A: Climate Change and the Water Cycle

Justify how climate change may affect each stage of the water cycle. Record your thoughts below, and then represent these changes in the diagram on the following page.

Your teacher may ask you to conduct online research to complete this task.

Our Changing Water Cycle



Part B: Impacts

Select one change to investigate further. Justify the impact this change may have on ecosystems, communities and industry, and explain how this change may affect the quantity and quality of water. Your teacher may ask you to conduct online research to complete this task.

Ecosystems	**Communities**	**Industry**

Water cycle change:

How will this change affect the QUANTITY of water?	**How will this change affect the QUALITY of water?**

Part C: Designed Solutions

Develop a designed solution that will minimise the impacts of this change on ecosystems, communities or industry. You will present your final solution to representatives from the State Government (your class and teacher).

You must:

- Investigate current solutions to improve this problem. Critique two current solutions by conducting a SWOT analysis. To complete the SWOT analysis, you will need to consider:
  - What are the best aspects of the solution? (Strengths)
  - What will not work so well with the solution? (Weaknesses)
  - What might you do differently if you designed the solution? (Opportunities)
  - What potential problems are there with the solution? (Threats)

  Develop criteria that solutions would need to meet in order to successfully improve the problem (success criteria).
- Design an innovative solution that will minimise the impacts of the water cycle change on ecosystems, communities or industry. During the design process, you should consider:
  - Success criteria
  - Materials, systems, components, tools and equipment, including their characteristics and properties
  - Ethical, economic, environmental and/or social sustainability factors and impacts
- Create a prototype of your solution.
- Test your designed solution and evaluate it against the success criteria.
- Refine your designed solution to better solve the problem and meet the success criteria.
- Evaluate the designed solution continuously against the success criteria, and make changes to improve the design.
- Collaborate with your team members, pitch your design and respond to feedback from other teams. You may also be required to evaluate social interactions to effectively work in a team.

Taking Action: Queensland Museum

Museums play a critical role in describing and conserving our natural history, and consequently can provide a unique insight into how climate change is affecting our biodiversity.

Queensland Museum collections and research demonstrate how species respond and adapt to climate change. Our collections provide information about changes in the population and distribution of species over time; the research of our scientists helps us to better understand how species are being affected by and are responding to changing climates.

A Chat with Dr Paul Oliver, Senior Curator of Mammals and Birds, Queensland Museum

Paul is the Senior Curator of Mammals and Birds at Queensland Museum. Learn about how Paul's research demonstrates the effects of changing climates below.

- **How did you become interested in your field of study?**

  The diversity and story of life on Earth simply blows my mind. I am a Systematist and Biogeographer; basically, this means I document the world's biological diversity (by discovering and naming new species), and I try to understand the processes that have shaped this diversity (by exploring why animals live where they do).

Dr Paul Oliver, working in the field.

- **What is your favourite part of your work?**

  Richard Dawkins, a famous British evolutionary biologist, once described evolution and biodiversity as, 'The greatest show on Earth.' And he was right. My job is to document and tell little tiny portions of a story that spans millions of species and billions of years. It is truly a privilege to be able to document completely new species, and then to try and understand the remarkable confluence of environmental and biological processes that have shaped them. Hopefully this information also inspires and informs efforts to conserve biodiversity.

- **Describe some of the projects you are currently working on.**

  I am working on a lot of things, to say the least. In terms of climate change, one of my big foci is trying to use genetic information to understand how species have responded to past climatic changes, especially across the rainforests and open woodlands of eastern Queensland.


Paul has been investigating how the animals and environments of central Queensland have responded to environmental change. Through this research, Paul has discovered that the distribution of the Brigalow Scaly-foot legless gecko (*Paradelma orientalis*) (left) has changed over time in response to climate change and the clearing of vegetation in the Brigalow Belt (right). Images: © Steve K Wilson.

- **Why did you decide to undertake these projects?**

  Climates have cooled and warmed over past glacial cycles. Understanding how animals have been affected by these past changes is potentially really important for predicting the consequences of the rapid climatic change we are currently experiencing.

  It is important here to emphasise that while the climate has changed for other reasons in the past, there is no doubt that the warming of over one degree we have seen over the last century is due to the greenhouse gases we have been pumping out into the atmosphere. Scientists can show a clear link between past climate change and the amount of carbon dioxide in the atmosphere; the source of the increase in carbon dioxide in the atmosphere over the last century is unequivocally people.

- **What have you learnt from these projects?**

  To be honest, the results of this work are deeply concerning. Lots of populations of animals and plants seem to have responded to past climatic change in a very dynamic way, with major expansions and contractions over hundreds or even thousands of kilometres of Queensland. However, the 2 - 3 degrees of warming we are expecting to see in my lifetime will be devastating for both biodiversity and the biological systems that sustain our society. The current climate is heading in a direction that most species have not previously experienced. Many species will simply have nowhere to retreat to as the climate warms; and for some of these species, pathways for dispersal into new habitats have already been decimated by human activities. It is clear that if we continue on current trends, the already high rate of species extinction we are currently experiencing is likely to increase significantly in the coming decades.

- **What actions do you take to reduce your carbon footprint?**

  We live in a society that is based around burning carbon-based fuels. This means we all have opportunities to reduce our carbon footprint. I drive a small car (as little as possible) and pay extra for electricity generated from renewable zero-carbon sources. My family try to buy food that has a lower carbon footprint. When voting, I pay a lot of attention to climate change policies, but also try to look for realistic pathways to transition away from carbon intensive industries. I am also increasingly reluctant to travel overseas or fly generally, and if I do, try and make the most of each trip, rather than having lots of short trips.

- **What would you recommend for students who would like to work in a similar field?**

  Be flexible and adaptable; it is highly unlikely that the pathway I took to get my job will be the same pathway that people take in 10 years' time. It is not even clear that jobs like mine will exist. The rate at which the economy and society is changing is unprecedented, and many of the key opportunities and challenges which are going to emerge over the next few years may not even be apparent now. All I can say is that if you think something is important and you want to do it, you are going to need to present clear arguments as to why it needs to be done, and get creative about seeking support to do it. I would also emphasise that education matters. Having a good education and a broad and considered worldview is critical to effectively addressing many of the key challenges we face.

What actions could you take to reduce your carbon footprint? Record your thoughts and ideas below.

A Chat with Dr Michael Rix, Principal Curator (Arachnology) and Head of Terrestrial Biodiversity, Queensland Museum

- **How did you become interested in your field of study?**

  I first became interested in spiders at the age of 10, when I saw what I thought to be an ant in some bushland near Brisbane. I realised it was *not* an ant when it looked up at me, and then abseiled down to a leaf on a line of silk! What I had found was actually an Ant-Mimicking Jumping Spider and from that moment on I was hooked! I soon discovered that spiders were endlessly fascinating, poorly known and terribly misunderstood, and I decided by about the age of 12 that I wanted to pursue a scientific career in arachnology. I've never looked back since!

Master of deception: an Ant-Mimicking Jumping Spider (genus *Myrmarachne*). Image: Caitlin Henderson.

- **What is your favourite part of your work?**

  As a spider taxonomist (someone who classifies and names new species) and evolutionary biologist (someone who studies the evolution of those species), the part of my work that I love the most is the process of discovery. Discovering species which are new to science never gets old, and in Australia, we have lots of new and amazing invertebrate species needing to be discovered and described. Indeed, some of my career-favourite moments have been those times in the field where I have encountered an especially exciting, rare or important species. But the process of discovery does not end in the field; back in the lab, when we do our scientific work, we can make other exciting discoveries as a result of careful research or astute observation. In the end, discovering new things is what science is all about, and I love it!

- **Describe some of the projects you are currently working on.**

  I have a number of research projects that I am currently working on, most of them related to a real passion of mine – Australia's trapdoor spiders. Australia is home to lots of amazing trapdoor spiders, and remarkably, the vast majority of these are scientifically undescribed; that is, they don't have a proper scientific name and are in most cases completely unstudied.

  Trapdoor spiders are amazing animals in their own right, and are incredibly important predators in our rainforests, eucalypt forests and inland desert ecosystems. Some can even live to over 40 years of age in the wild! Trapdoor spiders are also excellent indicator species for the health of the environment, especially in the face of climate change and environmental degradation.

Michael studying trapdoor spiders in the field. He spends a lot of time looking at the ground! Image: Alan Rix.

My main taxonomic project at present is all about a particular group of trapdoor spiders that live in Queensland's rainforests. These are commonly called Eastern Wishbone Spiders, and belong to the genus *Namea*. Only 15 species are currently described, but the Queensland Museum collection has specimens of many more additional species, and it is my job to name these.

Eastern Wishbone Spiders are really interesting animals. Unlike most trapdoor spiders, they don't build a little door at the entrance to their underground burrows and they are almost entirely restricted to rainforests. Because Australia's rainforests are themselves now only found in certain special places (usually the tops of mountains), some species of *Namea* have extremely small natural ranges. For these sorts of rare species, their continued survival requires first naming them (so that we know what they are), and then protecting the rainforests in which they live. In this respect, the process of taxonomy (i.e. naming species) has a crucial role to play in our efforts to also conserve biodiversity for future generations.

Unfortunately, rainforest organisms are among the most at risk from environmental changes resulting from climate change, especially those species with extremely small natural distributions and/or very specific habitat preferences. The recent fires during the 'black summer' of 2019/20 were a case in point: vast areas of rainforest burnt during this period, and it is still unclear just how big an impact these fires had on restricted invertebrates such as trapdoor spiders. To address this question, my colleagues and I are currently combining our taxonomic research (to ascertain what the species are, and where they are found), with detailed ecological field surveys (to ascertain where in the environment they can continue to survive, post-fire).

Two species of Eastern Wishbone Spider of the genus *Namea*. These spiders are at home in Queensland's tropical and subtropical rainforests. Images: Michael Rix.

A second project that I am currently working on concerns another group of trapdoor spiders, members of the genus *Aname*, which are more at home in Australia's inland deserts. These spiders also live in open-holed burrows, and like *Namea*, the vast majority of Aname species are still scientifically undescribed. However, our aim in this project is to try and understand how Australia's arid zone has evolved over time by studying the spiders that live there. This is a field known broadly as 'biogeography'.

Two species of *Aname* from inland Australia. These spiders are at home in Australia's driest and hottest environments. Images: Michael Rix.

For our project, we have used genetic information from the spiders to try and understand when and where different groups of species evolved over time, and how these patterns correlate to past climatic changes (e.g. the Australian arid zone only formed relatively recently, in response to successive phases of severe climatic aridification). This information then provides a 'window' into the past.

Indeed, the genes of all species (including ourselves) can tell scientists a lot about the evolutionary process, and museum scientists now use genetic information routinely to help them understand the species they work on. In the case of studying the evolutionary history of species from the arid zone, we learn about how the Australian fauna has adapted to past climatic shifts, which in turn can help us to understand how current climatic changes may drive future biotic change.

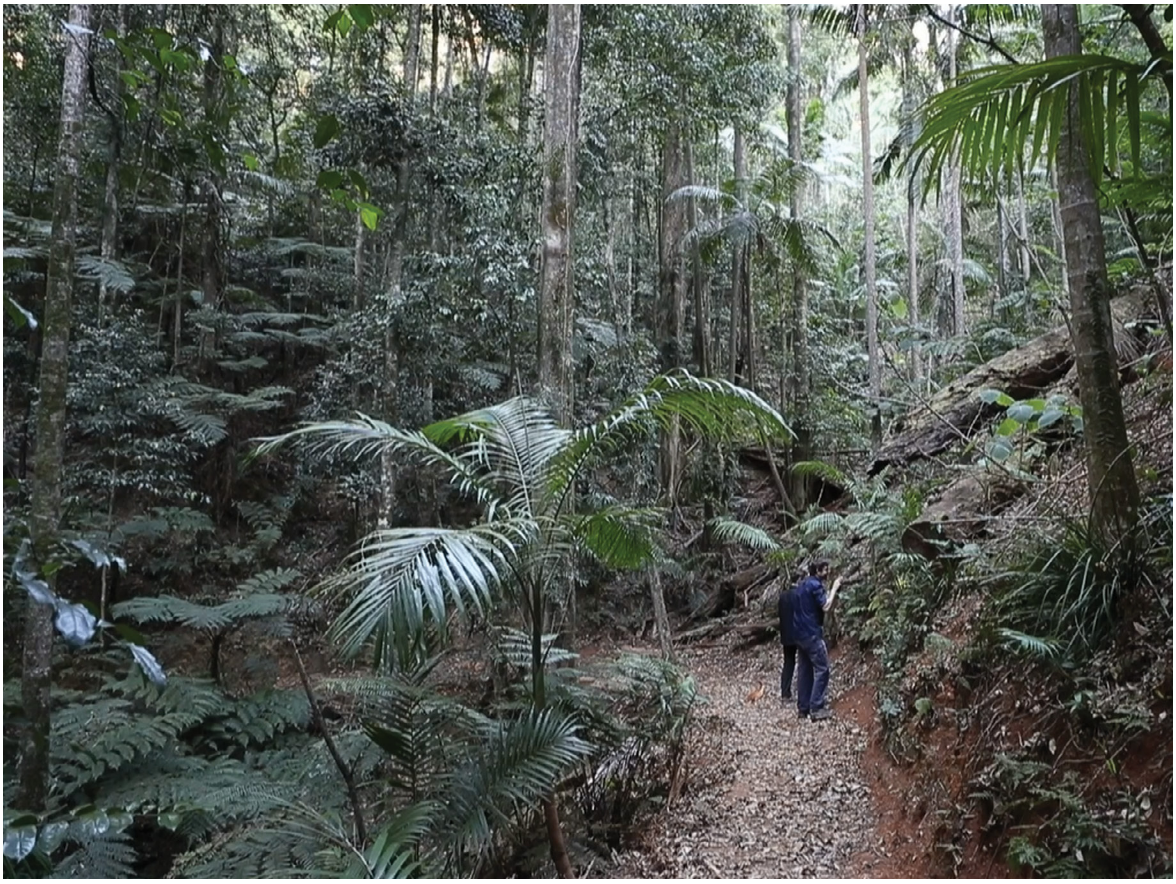
- **Why did you decide to undertake these projects?**

  Biodiversity amazes and inspires me, as planet Earth is still the only place in the universe we know of with organic life. And today we are all surrounded by a myriad of species which have evolved over millions of years. Understanding the origins of that biological diversity, and therefore generating the scientific information we need to conserve it for future generations in the face of unprecedented environmental change, is what drives me to do my research. However, I am also genuinely fascinated by the spiders themselves, and their role in the environment. Australia is home to remarkable spider fauna, and it is a privilege to be able to study them (and hopefully also help preserve them).

- **What have you learnt from these projects?**

  Studying the natural world is endlessly fascinating, and it never ceases to amaze me just how much we still have to learn about biodiversity. Australia itself is one of the most biodiverse countries on Earth, and over the last 10 years we have begun to realise just how remarkably diverse the Australian trapdoor spider fauna really are. Indeed, these projects have now revealed several hundred new and undescribed species in Australia.

For example, in Queensland, we have known for a long time that our rainforests are special places – cradles of biodiversity – and working on Eastern Wishbone Spiders has shown yet again that these rainforest habitats are home to numerous species found nowhere else. The job of discovering and describing these species is not an easy one, but it is essential that we understand what wildlife we are protecting in our national parks and native forests. In essence, if we do not know what lives in the environment, we cannot hope to prevent future extinctions.



Searching for trapdoor spiders in rainforest at Mount Glorious. Image: Peter Wallis.

With our genetic work on *Aname*, we have also discovered that the inland arid zone is far more interesting and diverse than it looks. As the Australian deserts formed over millions of years, trapdoor spiders moved into these habitats, where they then diversified and evolved into the species we see today. Places like the Pilbara and 'Wheatbelt' in Western Australia, and the Eyre Peninsula of South Australia, are home to an amazing diversity of arid-adapted trapdoor spiders, living out their lives in some of the harshest of environments.

However, some trapdoor spiders have a trick up their sleeves... they can burrow, deep underground, thereby avoiding the worst of conditions on the surface. Here they can spend decades, living for long periods with only small amounts of food. In this respect, in the face of severe climatic change, arid zone trapdoor spiders may be more adaptable and better survivors than their rainforest relatives. But we have also discovered that arid zone species are declining due to other factors, e.g. land clearing, grazing and dryland salinity. So, while they are indeed great survivors, they teach us that climate change and environmental destruction caused by humans are two sides of the same coin. For biodiversity to survive long-term, we must protect species, their habitats and Earth's climate system.

- **What actions do you take to reduce your carbon footprint?**

  As a biologist, I see the effects of climate change and environmental degradation all too clearly as part of my own research. In our family, we work hard to reduce our overall carbon footprint as much as possible, by recycling all of our soft plastics (through REDCycle), using a bokashi bin composting system for most of our food waste and growing our own vegetables. We also have solar panels on our roof to reduce our energy consumption, and we recently invested in building a new home which is designed to be as energy efficient as possible. Whenever we can, we also buy local and organic groceries, and I travel to and from the Museum on public transport as much as possible. It's not easy reducing one's carbon footprint, but it is important.

- **What would you recommend for students who would like to work in a similar field?**

  In my view, there has never been a more important time to be a biologist. The threats to our natural world are significant, and we therefore need dedicated, passionate young scientists to help understand and conserve our biodiversity for future generations.

  For students who are interested in a career in the natural sciences, my advice would be – what are you waiting for?! All of us can be students of science in our own right, and the best way to appreciate and learn about biodiversity is to immerse yourself in nature; by getting out into our stunning natural environments, by observing animals and plants up close, by reading amazing natural history books and reference guides, and by seeking out extra information online. This is the best preparation you could wish for prior to formal study.

  For those specifically interested in a career in taxonomy or evolutionary biology, the same rules apply: get out into nature, launch yourself into your studies and never look back. A scientific career can be a hard slog and requires lengthy study (which never really ends), but it is undoubtedly worth it.

What surprised or fascinated you the most about Michael's research? Record your thoughts and ideas below.