Introduction to Ocean Acidification

BIOLOGICAL SCIENCES — CHEMICAL SCIENCES — EARTH SCIENCES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK Queensland Government

Introduction

Coral reefs are iconic Queensland ecosystems, extending along nearly the entire coastline and out into the Coral Sea. The Great Barrier Reef is the largest coral reef ecosystem in the world and the largest structure ever built by living organisms. It is considered to be one of the most biodiverse marine habitats in the world. Estimates suggest that over 1500 fish species, 360 reef-building corals, 10,000 molluscs, 1500 sponge species, and numerous other marine species call the Great Barrier Reef home.

Queensland Museum has been an authority on the investigation, documentation and conservation of Queensland's biodiversity for over 153 years. This includes the study of our marine environment. Queensland Museum scientists have played a role in discovering more than 4000 new species since 1862!

Our Biodiversity Collections:

— Represent a pivotal resource for the study of tropical Australasian biodiversity.

— Provide verifiable records to gain new knowledge of Queensland's unique animals, and those that are also common elsewhere in the Asia-Pacific region.

— Provide an insight into the evolution, connectivity and dispersal of life throughout this region.

The Biodiversity Collection grows as we increase our inventory and understanding of Queensland's natural resources. This research continues today, and we still have a great deal more to learn.

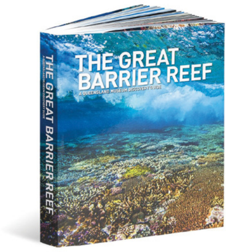
Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC project aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

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.

Resources

This resource may be used with Queensland Museum resource *Investigating Ocean Acidification* — an experimental investigation that explores the effect of ocean acidification on animals with calcium carbonate shells.

Other relevant resources include: The Queensland Museum Network *Field Guide to Queensland Fauna app* and *The Great Barrier Reef: A Queensland Museum Discovery Guide.*
The apps are free to download, while the book can be purchased from the Queensland Museum shop in-store or online.



The marine environment is on display in the *Wild State* exhibition at Queensland Museum, South Brisbane, and in *Colour - Secret Language of the Reef* at the Museum of Tropical Queensland, Townsville.

To learn what it is like to work on the Great Barrier Reef at the cutting edge of marine science, you can watch a short video of Dr Paul Muir as he explains what he loves about his job as a marine biologist with Queensland Museum.

Activity Overview
Introduction to Ocean Acidification

In this activity you will investigate how carbon dioxide (CO_2) affects the pH of water, and how carbon dioxide may affect fish and other marine species. You will then brainstorm changes that you can make to reduce your impact on the reef, research carbon capture and storage technology, and design a device to remove carbon dioxide from the atmosphere or ocean.

TEACHER TIPS

- Arrange students in groups of 3 – 4 to promote collaborative learning and communication.
- Use guiding questions when necessary, and include peer learning and feedback (for example, class discussions).

Activity 1

- Distilled water may be used for Activity 1 if tap water is already acidic.

Activity 2

- Your class may want to host a technology display for other classes, or parents.
- There are many local, national and international science competitions. You may wish to submit student carbon capture and storage prototypes to one of these competitions.

Australian Curriculum Links

YEAR 9

Science Understanding

Biological Sciences

Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems *(ACSSU176)*

Chemical Sciences

Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed *(ACSSU178)*

Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer *(ACSSU179)*

Science as a Human Endeavour

Values and needs of contemporary society can influence the focus of scientific research *(ACSHE228)*

People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities *(ACSHE160)*

Science Inquiry Skills

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence *(ACSIS170)*

YEAR 10

Science Understanding

Earth and Environmental Sciences

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere *(ACSSU189)*

Science as a Human Endeavour

Values and needs of contemporary society can influence the focus of scientific research *(ACSHE230)*

People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities *(ACSHE194)*

Science Inquiry Skills

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence *(ACSIS204)*

GENERAL CAPABILITIES

Numeracy

Understand and use numbers in context

Activity 1
An introduction to how carbon dioxide affects the ocean

Humans inhale oxygen (O_2) for energy (cellular respiration), and exhale carbon dioxide (CO_2). In this experiment you will use your breath to investigate the effect of carbon dioxide on water.

Objective

To identify how carbon dioxide affects water.

Materials

- 250 mL beaker
- 100 mL tap water
- Drinking straw
- Universal indicator

SAFETY FIRST

WEAR SAFETY GOGGLES
AND COVERED SHOES

Method

1. Pour 100 mL of tap water into a beaker.
2. Add 5 drops of universal indicator and measure the pH.
3. Place the straw into the water and gently blow bubbles.
4. Record the results.

Questions

1. Explain what happened when you exhaled carbon dioxide into the water.

The pH change may not seem like much, but...

The pH of a solution tells us how acidic or alkaline (basic) a substance is.

The acidity depends on the concentration of hydrogen ions, written as [H^+]. The greater the hydrogen ion concentration, the more acidic the solution (and the lower the pH).

The pH scale (Figure 1) is a 'logarithmic' scale (similar to the Richter scale for earthquakes). This means that every drop in pH value is 10 times more acidic than the value above: a pH of 6 is **TEN TIMES** more acidic than a pH of 7 (if this is converted to a percentage it would be 1000% more acidic)!

Since the industrial revolution, the pH of the oceans is estimated to have decreased from 8.2 to 8.1[1]. This may not seem like much, but because pH is logarithmic, this accounts for a 25 to 30% increase in acidity!

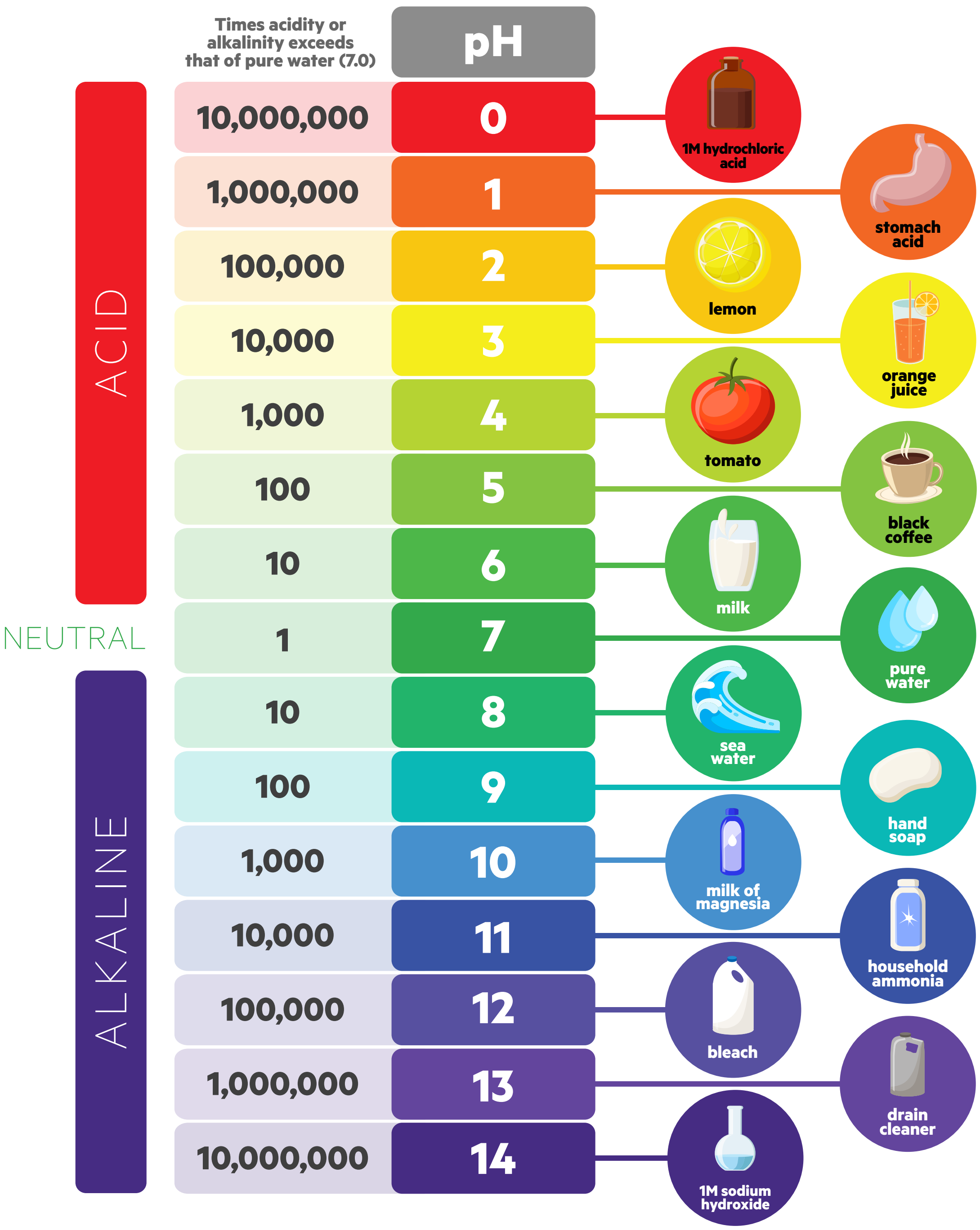


Figure 1: pH of household objects

2. Using the universal indicator chart, calculate the change in pH of your solution and then convert this to a percentage. This is how much the CO_2 in your breath has changed the acidity of the water!

3. Use the above experiment to explain how and why the world's oceans are becoming more acidic.

Further investigations

- Try comparing fresh water with sea water. Fill one beaker with 100 mL of fresh water, and one with 100 mL of sea water. Add 5 drops of universal indicator and gently blow bubbles into each beaker for 2 minutes. Observe differences in pH and explain your results. (If sea water is not available, a substitute can be made by dissolving 30 g of common salt (sodium chloride) in 1 L of water.)
- Design an experiment to investigate the pH change in exhaled breath before and after exercise. Remember to keep your experiment fair by controlling the variables. You should write a justified hypothesis before you conduct the experiment. This activity links to the human body and homeostasis.

Poor Nemo! The effect of ocean acidification on marine animals

Ocean acidification can have unexpected consequences for many marine species. Recent studies have shown that even slight increases in acidity can disrupt the sensory organs of many marine animals including fish, gastropods and crustaceans.

Clownfish (Figure 2) normally avoid predators by detecting their odour. However, studies have found that when the pH is decreased by even 0.3, clownfish (and many other species) begin to lose their sensory abilities. Clownfish may even start swimming towards predators[2]! The disruption of sensory systems due to changes in pH can also make it difficult for juvenile clownfish locate coral reefs[3].

Similarly, slight increases in acidity prevent some gastropods from detecting direction, including up and down. As a result, the gastropods cannot right themselves if they are knocked over. Additionally, hermit crabs find it hard to choose an appropriate shell, and are very slow at returning to their shells to escape predators[4]. This may decrease the survival of these organisms.

Ocean acidification also affects marine organisms with calcium carbonate shells and exoskeletons. You can investigate this in the Queensland Museum resource – *Investigating Ocean Acidification*.

To understand the impacts of human activity on coral reef ecosystems, it is important for scientists like Dr Tom Bridge to study reefs (page 10).

Figure 2: Clownfish have a mutualistic symbiotic relationship with sea anemones in which both organisms offer protection to one another. The clownfish is not stung by the sea anemone, and chases away butterflyfish which would eat the anemone. Look at the Queensland Museum resource Specialised Stinging Cells to learn how stinging nematocysts work. Image: QM, Gary Cranitch

STEM CAREERS IN REAL LIFE:
Dr Tom Bridge, Biologist

Dr Tom Bridge is the Queensland Museum's Senior Curator of Corals, based at the Museum of Tropical Queensland in Townsville. He studies the biodiversity, ecology and conservation of coral reefs, is an underwater photographer, and looks after the museum's internationally-renowned coral collection.

Figure 3: Dr Tom Bridge at the Museum of Tropical Queensland in Townsville. Image: Queensland Museum

Historically, the vast majority of research investigating coral reefs has focussed on shallow reefs. Dr Bridge uses new technology to explore reefs living in the deeper waters known as the 'twilight zone', or the 'mesophotic zone'. Mesophotic coral reefs are found below 30 m in depth, and support diverse ecological communities, including many species new to science, and other species not previously recorded in Australia. These depths are so new to research that (on some dives) a new fish species may be discovered every 5 to 10 minutes!

Mesophotic coral reefs are below the depths accessible to conventional SCUBA divers. Instead, Dr Bridge uses cutting-edge technology: autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs). These vehicles are used to collect images, specimens and environmental data from mesophotic reefs. Closed-circuit rebreathers can also be used by scientists like Dr Bridge to dive to depths up to 150 m below the surface. This work therefore requires an extensive knowledge of coral reef biodiversity, as well as excellent technical diving skills.

Coral reefs are the most diverse marine ecosystems on Earth, but are increasingly threatened by multiple stressors, on both local and global scales. The decline in shallow-water reefs is a threat to the food security of millions of people who rely on the reefs for food and income. However, deeper areas in the mesophotic zone appear to be more protected from threats (such as elevated temperatures and storms) that affect corals in shallower waters. As a result, the deeper reefs may play an important role in preserving coral reef biodiversity by acting as refuges for marine organisms. However, mesophotic coral reefs will still be vulnerable to the effects of ocean acidification.

It is important that we work together now to protect deep and shallow reefs. Protecting our coral reefs will not only prevent the extinction of many species, and preserve these ecosystems for future generations; it will also deliver social and economic benefits.

Activity 2
Reducing Human Impact

1. Human impact on the environment is resulting in rapid and dramatic species loss. We all have the ability and responsibility to make a difference. Think of one thing that you can do today to reduce your impact on the environment.

Figure 4: Corals create the structure of the reef that provides homes for a great diversity of organisms, including fish, crustaceans, sponges, worms, snails, slugs and starfish. Here you can see a mixed school of colourful anthias and fusiliers. Image: QM, Gary Cranitch

Atmospheric carbon dioxide levels are the highest they have been in human history, and possibly the last 20 million years[5]. Other evidence suggests that carbon dioxide levels have not been this high since the Pliocene, three to five million years ago. During the Pliocene, temperatures were up to 10°C hotter than today. As a result, sea levels were at least 15 m to 25 m above present levels[6].

A sea level rise of 15 m to 25 m today would put many cities at risk of flooding. It could also increase frequency and intensity of storms, and change rain and drought patterns, potentially threatening food and water supplies. As current climate change is happening rapidly, species are less likely to be able to adapt and evolve to survive the changing conditions. Species that cannot adapt to these changes are likely to become extinct.

To reduce the impact of climate change, many scientists are developing technologies to remove carbon dioxide from the atmosphere and oceans. This is often referred to as carbon capture and storage.

2. Research a technology that has the potential to remove carbon dioxide from the atmosphere or oceans. Explain how it works, and present your research to the class as an individual display. This may include a poster, presentation, animation, comic strip, children's story book, newspaper article, interview, podcast, or documentary. You may use the space below for planning and background information.

Activity 3
Design Challenge

Use the research that you and your class have completed to design your own carbon capture and storage technology!

Design
Draw a diagram of your new carbon capture and storage solution.

Communicate
Explain how and why your design will remove carbon dioxide from the atmosphere.

Create
Create a prototype of your design that you can test at home or at school. Dissolved carbon dioxide in water can be tested qualitatively using universal indicator as in Activity 1, or you may research alternative methods to test carbon dioxide concentration.

References

[1] National Oceanic and Atmospheric Adminstration (NOAA). (2017). *Ocean Acidification: Surface pH.* Retrieved from: https://sos.noaa.gov/datasets/ocean-acidification-surface-ph/

[2] Leduc, A., Munday, P., Brown, G. and Ferrari, M. (2013). Effects of acidification on olfactory-mediated behaviour in freshwater and marine ecosystems: a synthesis. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 368(1627), 20120447-20120447.

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[4] Kim, T., Taylor, J., Lovera, C. and Barry, J. (2015). CO_2-driven decrease in pH disrupts olfactory behaviour and increases individual variation in deep-sea hermit crabs. *ICES Journal of Marine Science: Journal du Conseil*, 73(3), 613-619.

[5] Hoegh-Guldberg, O., Mumby, P., Hooten, A., Steneck, R., Greenfield, P., Gomez, E., ... Hatziolos, M. (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science,* 318(5857), 1737-1742.

[6] Intergovernmental Panel on Climate Change. (2007). *IPCC Fourth Assessment Report: Climate Change 2007. 6.3.2 What Does the Record of the Mid-Pliocene Show?* [online]. Retrieved from: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch6s6-3-2.html