BUG LAB

LEARNING RESOURCE

Auckland ZOO

Regional Facilities Auckland
An Auckland Council Organisation

This exhibition has been developed by the Museum of New Zealand Te Papa Tongarewa with Weta Workshop Limited

Weta Workshop

Te Papa Our Place

BUG LAB LEARNING RESOURCE

This resource has been written to accompany *Bug Lab*, an exhibition about how bugs are sharing their biggest secrets and inspiring human innovation. The resource is aimed at primary to intermediate students. It's designed to inspire, rather than instruct, and will empower a multidisciplinary investigation of insects, spiders, and their relatives.

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Praying Mantis. CC0

INTRODUCTION

0.1 *Bug Lab*: The exhibition

What if the planet's smallest geniuses could share their biggest secrets? *Bug Lab* is a science exhibition like no other, presented by the incredible bugs themselves.

Enter the bugs' world, marvel at their talents, and witness them in action. Meet the smartest of these micro-masters and face their most fiendish tests. Can you match the dragonfly's speed, or beat the mantis's reflexes?

The bugs' biggest challenge to us is to learn from their genius. Precision flight, swarm intelligence, mind control … bugs did it all first, and still do it better. What would the future look like if we could match their brilliance?

Exhibition themes:

1. The bug world is full of genius, developed over millions of years in nature's research and design lab.
2. Bugs are the inspiration for leading-edge technologies that can help solve human problems.

Honeybee

0.2 About the resource

This resource complements STEM- and STEAM-based educational practice. It is a collection of inquiry provocations and activities designed to encourage curiosity and understanding about bugs before or after visiting the *Bug Lab* exhibition.

The resource encourages investigation of bugs from multiple perspectives, using many different scientific and creative methods. All activities emphasise the four 21st-century core educational competencies: Collaboration, Communication, Creativity, and Critical Thinking.

There are three chapters, and each asks an essential question:

- What are bugs?
- What can we learn from bugs?
- How do we live with bugs?

Each chapter contains exhibition-related information, followed by adaptable **activities** for exploration in the classroom.

At the end of the resource, there is an appendix with a glossary, curriculum links, useful website references and supporting materials.

0.3 Essential questions

By asking three simple questions, we can expand our understanding of and appreciation for bugs.

Each of the three lines of inquiry can be investigated without knowledge of the other two.

1. **What are bugs?**

   There's so much that is still unknown about bugs. Scientists are constantly discovering and naming new species. One of the most helpful things we can do for science is to collect data about our local bug populations. Even very basic data collection is useful. However, it helps scientists if we know where to look for bugs, and can identify the difference between an insect and an arachnid. Find out if an intensive surveying attempt is happening in your local area by using the search word 'bioblitz' online.

2. **What can we learn from bugs?**

   When we explore the incredible world of bugs, we realise just how much we can learn from them. Humans have looked to bugs for assistance in many different scientific fields. Recent technological advances have allowed scientists to uncover even greater details about bugs and their life cycles, and to understand some of their unbelievable secrets. Whenever you look at a bug, you can always ask: 'What can this bug teach me?'

3. **How do we live with bugs?**

   It's not always easy to live with bugs, but we couldn't live without them. With greater awareness of bugs and what can be learned from them, we can better appreciate the ways in which human and bug lives intersect. What do we want for our future? Will bugs help us get there? What does that mean about the way we choose to live with bugs? Should we use less insecticide or just better insecticide? Should we eat bugs?

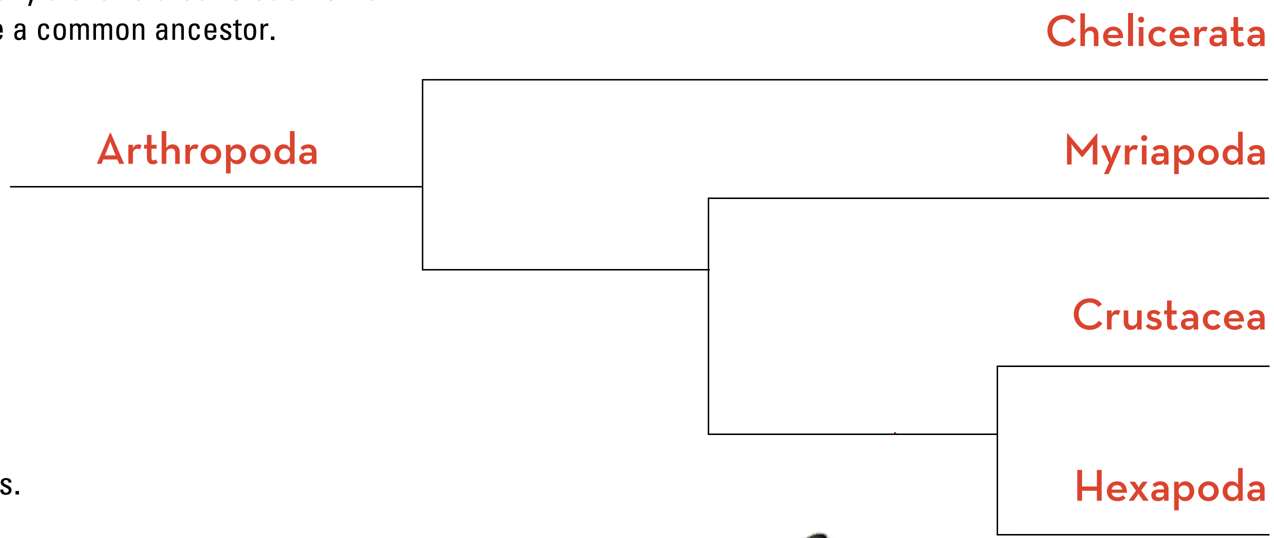
Morpho butterfly

CHAPTER 1: WHAT ARE BUGS?
Natural History and Exhibition Background

When people talk about bugs, they usually mean terrestrial arthropods. 'Terrestrial' means they live on the land, rather than in water.

Arthropods are animals with hard exoskeletons and jointed legs that belong to the phylum Arthropoda, which is divided into four subphyla.

The diagram below shows how the four subphyla are related to each other. The line splits in two where two groups have a common ancestor.



Chelicerata – eg, spiders and scorpions.

Myriapoda – eg, centipedes and millipedes.

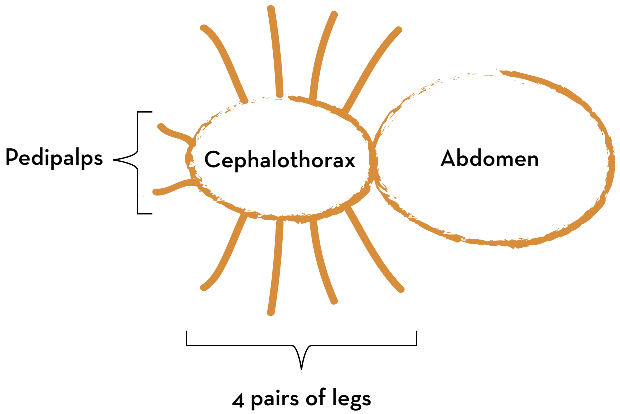
Crustacea – eg, slaters, crabs, and lobsters.

Hexapoda – eg, ants, butterflies, and beetles.

A basic introduction to the four groups follows. Use the references in the Appendix (4.3) to help you further investigate the differences between these groups.

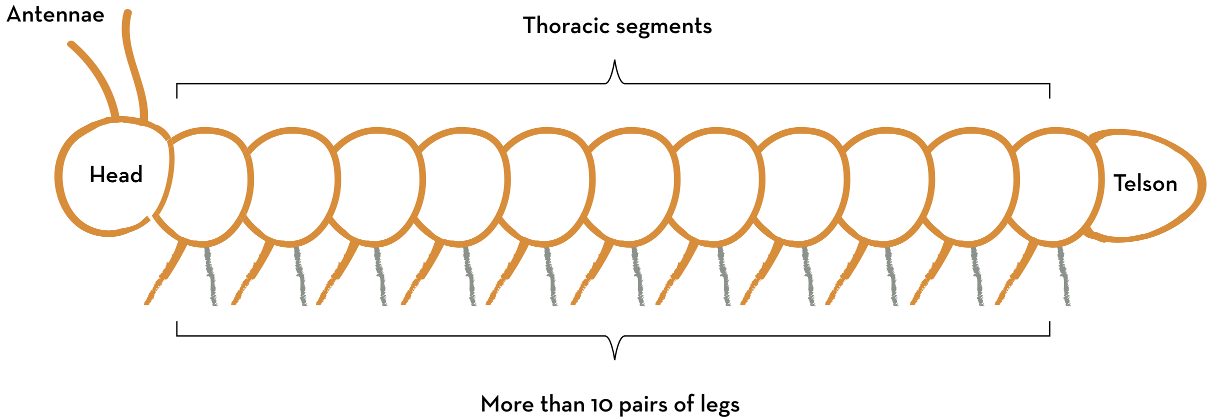
Queen Alexandra's birdwing, the largest butterfly in the world

1.0.1 Chelicerata



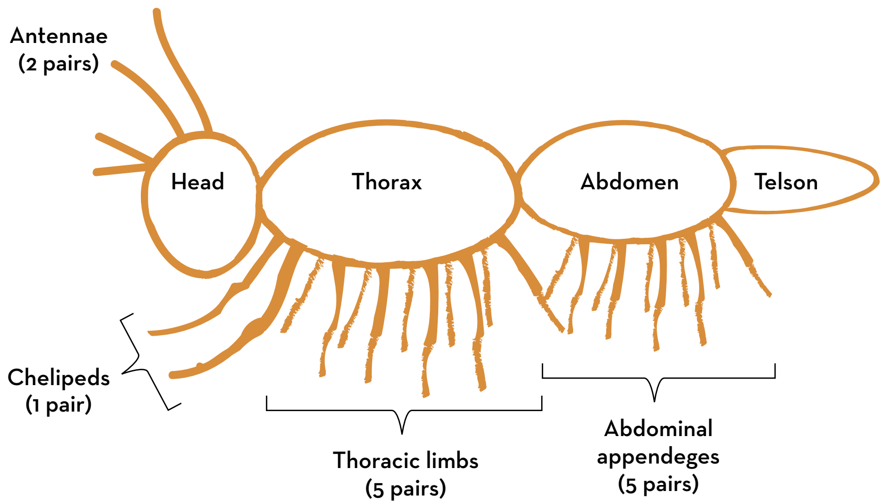
- ➜ Chelicerata includes arachnids.
- ➜ The head and thorax are fused into one body segment: the cephalothorax.
- ➜ Arachnids do not have wings or antennae, and most can't eat solid foods.
- ➜ The pedipalps of some arachnids are long enough to look like a fifth pair of legs.
- ➜ The abdomen of a scorpion is specially adapted to form its striking tail.

1.0.2 Myriapoda



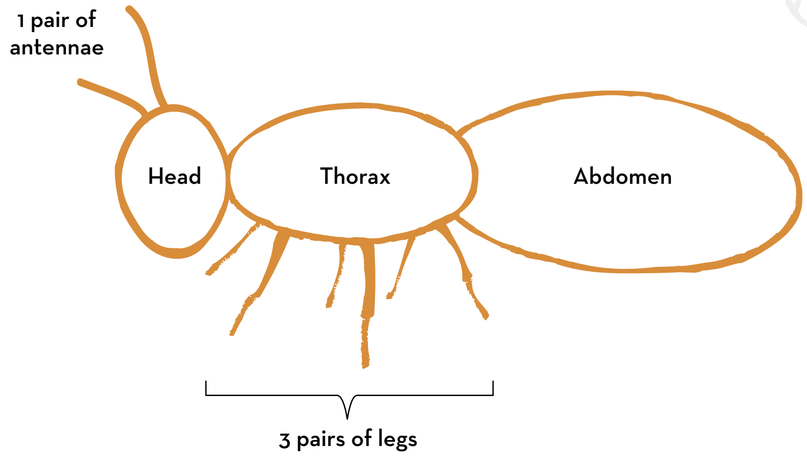
- ➜ One millipede species has 750 legs – more than any other animal in the world.
- ➜ Millipedes have two pairs of legs on each segment. Centipedes have only one pair on each segment.
- ➜ Some prehistoric millipedes grew to over 2 metres long.
- ➜ A 30-centimetre-long giant centipede from South America can eat lizards, frogs, mice, birds – and even bats that it catches mid-flight.

1.0.3 Crustacea



- In some crustacean species, the head and thorax are fused into a single cephalothorax.
- Appendages and limbs are often biramous, which means they branch into two parts.
- The cheliped is often a specialised limb, like the claws of lobsters and crabs.
- The telson never has appendages but can form a tail fan that aids swimming.
- The large number of appendages allows crustaceans to be highly specialised. They are the most diverse group of animals after insects.
- Crustacean species dominate the oceans, and some live in the deepest oceanic trenches.

1.0.4 Hexapoda



- Hexapods are named for their most distinctive feature: six legs.
- Hexapoda includes insects as well as three much smaller groups of wingless arthropods.
- Insects are the most diverse group of animals on the planet.
- Insects make up more than half the species of all known living animals.
- Above is the basic body plan of an insect. However, with the addition of wings, pincers, or mouthparts, insects can look quite different from this.
- The largest insect was an extinct relative of the dragonfly that had a wingspan of nearly 70 centimetres.

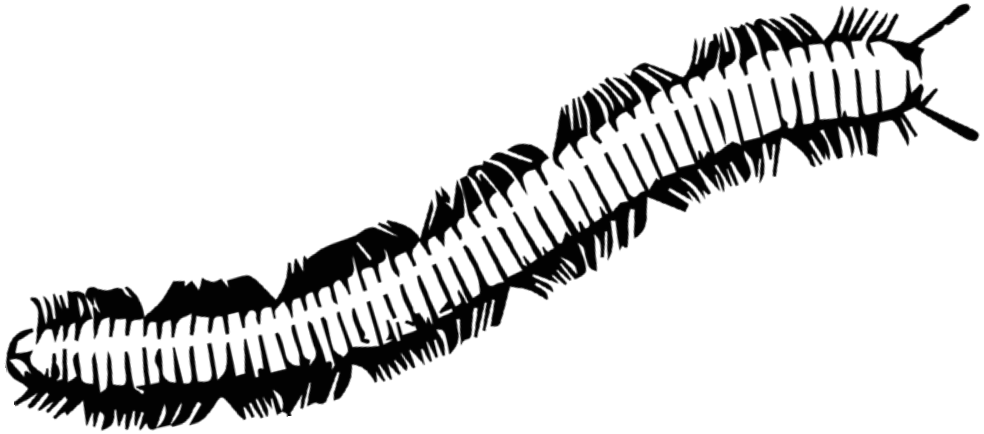
1.0.5 Bugs have been around for millions of years

The first example of a fossil record of an arthropod clearly adapted for life on land is of a *Pneumodesmus newmani*, a 428-million-year-old millipede.

Over 400 million years has been plenty of time for arthropods to become the most diverse group of animals on the planet. There are now more than:

- ➜ 98,000 arachnid species
- ➜ 13,000 myriapod species
- ➜ 67,000 crustacean species
- ➜ 1 million insect species

Two millipedes by Muhammad Mahdi Karim



1.0.6 Amazing bugs of *Bug Lab*

Orchid mantis (*Hymenopus coronatus*)

Fairest and deadliest of them all

Orchid mantis by Frupus

The orchid mantis is a stunning example of mimicry from the animal kingdom. When scientists first described this insect, they thought it was a carnivorous flower. We've only recently learned that the orchid mantis doesn't use its flowery form to hide at all. Instead it tries to stand out from the flowers around it. It is so good at pretending to be a flower that pollinating insects will choose to visit it rather than a neighbouring flower. That's when it uses its lightning-fast reflexes to snatch its prey right out of the air.

Smith's dragonfly (*Procordulia smithii*)

Flying ace

Dragonfly. CCO

Dragonflies have been flying for over 300 million years. They are an engineering masterpiece, with extremely good visual processing, strategic hunting, and acrobatic flight capability. This combination of expertise makes the dragonfly one of the most successful hunters in the animal kingdom, with almost 100% of hunts resulting in a meal.

Human aviation is just over a century old and has been primarily powered gliding. But we're doing what we can to catch up with the dragonfly's skill. We're experimenting with micro aerial vehicles (MAVs) to help us understand the limits and potential of the physics of flight.

Jewel wasp (*Ampulex compressa*)

Zombie brain surgeon

The female jewel wasp is a dedicated mother. She makes sure her offspring have the perfect incubator: a live cockroach. The jewel wasp stings the cockroach to briefly paralyse its front legs. Then, a second, far more precise sting in the cockroach's brain makes it lose its desire to escape.

The jewel wasp then leads the cockroach to a burrow, lays a single egg on its leg, and seals the entrance. After one month, a new adult wasp crawls from the burrow to search for a mate and, if it's a female, a cockroach.

American cockroach (*Periplaneta americana*)

Super-speedy survivor

Cockroaches have been around for over 320 million years, and are among the most adaptable animals on Earth. They are happy in almost any environment, from the freezing Arctic to sweltering tropical cities. There are approximately 4,600 species of cockroach, but only about 30 come into contact with humans.

The American cockroach was not originally a native of America–it migrated with sailors from Africa as early as 1625 and quickly made itself at home. It is considered one of the fastest-running insects, with a top recorded speed of 5.4km/h – about 50 body lengths per second. This is the equivalent of a human running at 330km/h.

American cockroaches will eat almost anything, including glue, dead skin, dead animals, plants, soiled clothing – and even other dead or injured cockroaches. It can survive for a month without eating, two weeks without drinking, and up to a week without its head!

American cockroach

Japanese honeybee (*Apis cerana japonica*)

Cooperative comrades

Hornet and bee battle by Dane Madgawick. Weta

Honeybees have been providing humans with honey for at least 8,000 years. They have an essential role in the world's ecosystem as pollinators, and without them most of our food crops wouldn't reproduce or grow fruit. There can be as many as 60,000 bees in a colony, nearly all daughters of a single queen, and all working together to raise young and make honey.

Honeybees must defend their hives from many different animals, including birds, reptiles, and mammals. Even other insects are known to kill bees to get to their honey. The Japanese giant hornet is one of the honeybee's most lethal enemies. Due to the hornet's size, armour, and appetite, most bees don't stand a chance. The hornets send out solitary hunters to find food. When one of these scout hornets finds a hive, it uses pheromones (invisible chemicals) to signal other hornets to come and destroy the hive.

However, Japanese honeybees have devised an ingenious defence. They can detect the hornet's pheromone too, and they know it means trouble. They have to move fast before more hornets detect the pheromone. They mob the hornet, and raise its temperature by vibrating their wing muscles incredibly fast. Japanese honeybees can survive slightly hotter temperatures than hornets, so the solitary hornet gets cooked to death. Honeybees are the masters of teamwork.

Japanese giant hornet (*Vespa mandarinia japonica*)

Team terminator

Japanese giant hornet by T-mizo

The Japanese giant hornet is the world's largest hornet species, with queens larger than 5 centimetres and workers approximately 4 centimetres long. They have a formidable stinger that's 6 millimetres long, which they use to inject large quantities of potent venom. The venom contains cytolytic proteins, which cause cells to burst open, and a neurotoxin that damages nerves. One scientist described a sting from one of these hornets as feeling 'like a hot nail being driven into my leg'.

Japanese giant hornets are predatory and hunt medium to large insects, including bees, mantises, and other hornets. However, the adult hornets cannot digest the protein from raw insects. The reason they hunt is to feed chewed-up insects to their developing larvae. The larvae then secrete a nutritious liquid back to the adults.

The larvae bang on their cell walls when they're hungry, which prompts the adults to look for food. This is the reason the Japanese giant hornet searches out honeybee colonies. A single hornet can kill up to 40 honeybees a minute, while a small team of fewer than 50 can destroy a colony of tens of thousands in a couple of hours. The hornets then steal the bee larvae to feed to their own larvae.

Katipō (*Latrodectus katipo*)

Deadly night stinger

The katipō spider is endemic to New Zealand, which means it's not found anywhere else in the world. Its name means 'night stinger' in te reo Māori. It's the country's only endemic venomous spider and is related to the Australian redback and the American black widow. Katipō live on the windy coasts of New Zealand and spin cobwebs amongst the native beach grasses. The wind blows crawling insects into these snares where katipō incapacitate them with their powerful venom.

Although katipō webs appear messy, there is purpose to every strand of silk. Some strands anchor to the ground, and unsuspecting insects get tangled up in them. As an insect struggles, some of the anchor lines can break. This hoists the insect into the air, where it can't escape. With their extremely strong silk, spiders like the katipō are able to capture prey much larger than themselves.

Katipō spider

Wētā (Anostostomatidae)

More than meets the eye

Wētā are endemic to New Zealand. There are approximately 70 species. Wētā look similar to their relatives: grasshoppers, locusts, and crickets. Like them, they have powerful hind legs and ears on their front legs. Wētā commonly have long antennae and large spikes on their hind legs.

Wētā are some of the heaviest insects in the world. They can grow to more than 10 centimetres long and weigh 20 to 30 grams, the same weight as a sparrow. Māori believe the wētāpunga, the giant weta, is the offspring of Punga, god of ugly things. It was one of the many insects sent by Whiro to attack his younger brother Tāne as he ascended the heavens to retrieve the three baskets of knowledge. Can you look beyond the ugly exterior of some bugs to find wonder and understanding?

Wētā by Kate Whitley. Te Papa

Pepetuna (*Aenetus virescens*)

Giant killer

The pepetuna, also known as the pūriri moth, is New Zealand's largest native moth, with a wingspan of up to 15 centimetres and a distinctive bright-green colour. It lives for just 48 hours as an adult moth, although it can survive for up to six years as a grub. The grub is known as a mokoroa, and makes its home in the pūriri tree, a huge evergreen that can grow to 20 metres tall, with a trunk wider than 1.5 metres in diameter.

The mokoroa gnaws its way through the bark and creates a distinctive burrow in the shape of a number 7. As the tree tries to heal, it produces sap that the mokoroa feeds on. Once the grub reaches about 10 centimetres long and 1.5 centimetres wide, it then pupates inside the burrow. The pupa then wriggles out of the tree and splits open, and the moth then flies away to mate and die.

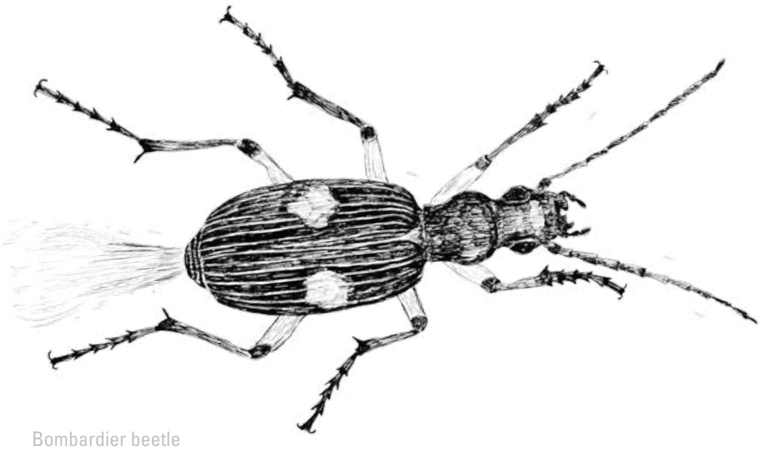
Large infestations of mokoroa can kill even the largest pūriri trees. Māori have a saying: 'He iti mokoroa e hinga pūriri', which translates as 'The little mokoroa grub fells a pūriri tree'. This proverb reminds people that the collective actions of small things can have a big impact.

Bombardier beetle (*Stenaptinus insignis*)

Bug blaster

Beetles are the most diverse insect group in the world, with over 400,000 species. There are more than 500 species of bombardier beetle worldwide, and they're found on every continent except Antarctica. They're carnivorous and hunt at night for insects.

The defence mechanism that gives the bombardier beetle its name is made up of a complex system of glands in its abdomen. These glands allow the beetle to mix two chemicals to create an explosive reaction that shoots out of its abdomen in a pulsing, high-pressure jet spray. Its abdomen is flexible enough for it to aim this hot, smelly explosion at any attacking insect or spider.



Bombardier beetle

Mosquito (Culicidae)

Brilliant bloodsucker

Mosquitoes are experts at finding a meal, but only the female drinks blood – she needs protein-rich food to produce her eggs. To maximise her success in finding food, she has a suite of highly attuned senses.

The mosquito's antennae can 'smell' the carbon dioxide we breathe out from over 30 metres away. Wide-angled, compound eyes are very sensitive to movement – and when mosquitoes get close enough, they can detect our body heat.

A mosquito lands so softly on our skin that we don't even feel it. Its piercing mouthpart, called a proboscis, is a complex arrangement of needles, blades, and tubes that painlessly pierce our skin. The bite we feel only happens when the mosquito has finished drinking and pulls away. The itchiness is created by the mosquito's saliva, which it uses to make sure our blood doesn't clot and clog up its proboscis.

A female mosquito can triple her body weight in less than two minutes of feeding. She uses the blood to help create up to 300 eggs.

Mosquito

1.1 Bugs in your environment

Go out and collect some bugs from your local area, then discuss and compare what you find.

Materials:

Pencil	Paper

Optional extras:

Magnifying glass	Shallow tray
Trowel	Camera
Colouring pencils	Large white sheet
Butterfly sweep net	Quadrat (frame to focus survey sampling)

This activity is a great opportunity to discuss what you expect to find in your local environment, and then compare that with what you actually find. If this is the first time you've looked for bugs, working in small teams is recommended. Have someone record what is found while others look for bugs.

Make a record of what you see by writing or drawing on paper, or using a camera. The more evidence of what's collected the better. Those who are looking for bugs may find magnifying glasses, trowels, quadrats, trays, and white paper useful. Trays are helpful for sorting leaf litter, while a white-paper background makes it easier to see any bugs. A good trick is to spread the leaf litter out thinly and wait a few moments. If a speck of dirt starts moving, then you know it's a bug!

An effective way to catch bugs is to stretch out a large, white sheet under a tree, then gently shake a branch. Bugs that live in the tree canopy will fall down onto the sheet. Teams can then investigate and record what they see. You can use the shallow trays if you don't have the space to stretch out a large sheet. Try it with different types of trees. Do you get different bugs? More bugs?

Activity

Use challenges to encourage searching for bugs. Find:

- the bug with the most legs
- the bug with the fewest legs
- the biggest bug
- the smallest bug
- the fastest bug
- the slowest bug
- the most colourful bug.


Cicada

For further ideas about finding bugs, see the references section in the Appendix (4.3).

1.2 Bug ecology

Make a bug timeline, learn about the Māori whakapapa (genealogy) of bugs, and discover some of the jobs that bugs do to help humans.

1.2.1 Millions of years of bugs

Ecology is the study of how plants and animals fit into an environment, and what their relationships are with other plants and animals.

Most bugs have to be good at hiding so they don't get eaten. They've been doing this for over 400 million years – only the best have survived to pass on their skills.

To put 400 million years into perspective, use the timeline from the supporting materials section in the Appendix (4.4.1).

- Pace out the timeline on a sports field and have people hold up signs.
- Draw it on a roll of toilet paper (the squares make a useful scale).
- Create it on a classroom wall.

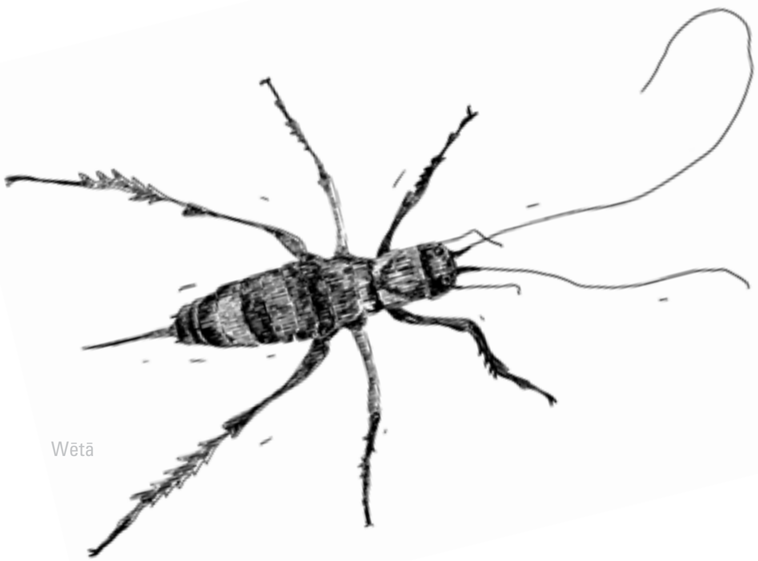
Activity

1.2.2 Cultural perspectives on bugs

Another way to express where bugs come from is to investigate the Māori whakapapa of bugs. Whakapapa is genealogy that traces the origins and interconnectedness of all things. For a more detailed illustration of the whakapapa of bugs, see the supporting materials section of the Appendix (4.4.2).

Māori have a holistic view of the natural world and, unlike biological science, don't describe bugs as entities separate from the environments where they are found. Spiderwebs are viewed as extensions of the spider, while the kūmara moth, a pest to kūmara (sweet potato) farmers, is accepted as an intrinsic part of the natural ecosystem.

Studying the whakapapa of bugs is like following references through scientific papers to show the evolution of our understanding of the natural world. In both approaches, knowledge is passed down through time, whether it is through oral tradition or scientific papers.



Wētā

The insect world

Te Aitanga-a-Pepeke

Ranginui + **Papatūānuku**
Sky father — Earth mother

Tāne + **Hine-tūpari-maunga**
God of forests, birds, and humans — Ancestor of mountains

Te Pūtoto + **Takaaho**
Ancestor of lava and red clay — Sea monster

Tūteāhuru + **Hinepeke**
Ancestor of insects — Ancestor of insects and lizards

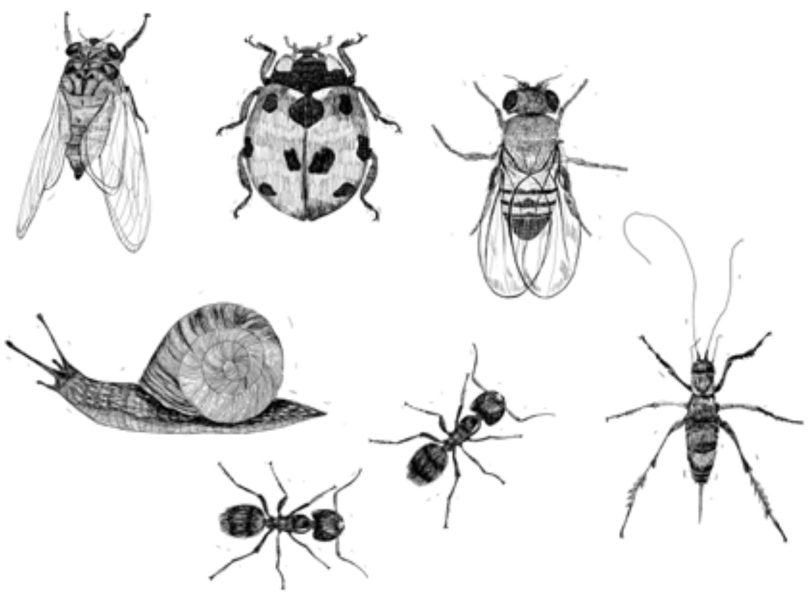
Te Aitanga-a-Pepeke
All insects, spiders, lizards, and vermin

1.2.3 Ecosystem services

Bugs are important facilitators of many of the natural cycles on the Earth. The jobs they do are known as ecosystem services. Some examples include:

- ➜ pollinating plants that produce food
- ➜ being food for larger animals
- ➜ pest control
- ➜ dung burial

These services have huge benefits for humans. We are dependent on insect pollinators for the food we eat, including fruit, nuts, vegetables, and chocolate. Learning about ecosystem services might change your perspective on the insects in your garden.



1.3 Bug physiology

Activity

Magnify some bugs and appreciate their fascinating details.

Materials:

Pencil
Paper
Magnifying glass

Optional extras:

Camera
Coloured pencils
Microscope
Tweezers
Pins
Polystyrene or cardboard sheet

Physiology is the study of how the body parts of an organism function, and what the organism is made of.

Look closely at some bugs to see what they're made of. Try to identify all of their moving parts. You'll need some magnification to really appreciate what's going on. Pins and tweezers can be used to carefully move dead insects under a microscope.

This activity is a great opportunity to try drawing or writing about bugs in as much detail as possible. While the bugs are under strong magnification, you can investigate the colours, shapes, and patterns of their bodies.

1.4 Bug behaviour

Observe bugs in their natural environments, or carefully keep one in captivity, and find out about their daily lives and needs.

Materials:

Bug-friendlly container	Magnifying glass
Pencil	Paper

Optional extras:

Camera	Paint
Microscope	Forceps
Desk lamp	Plants or leaves

Ladybird

Activity

1.4.1 Keeping bugs in captivity

There is plenty to learn from bugs by watching them go about their lives – either in their natural environment or in captivity. Keeping them in captivity allows you to control the environment so they're easier to observe. The challenge of looking after their needs can offer many learning opportunities.

Start with bugs you can find in your local environment. That way you'll know their food source is nearby. There is a fantastic guide to keeping bugs at www.bugsed.com that will help you keep your bugs safe and healthy.

1.4.2 Humane experiments

Humane experiments are another excellent way to learn about bugs. You can ask lots of questions about their reactions to environments or stimuli. Making a record of these interactions can be challenging and interesting because they take place over a period of time. It's good to discuss the best way to share your discoveries. If you have access to a camera, you could create stop-motion animation of the live bugs, or a photographic journal of the experiments.

Example questions to investigate:

- ➜ Do bugs prefer light or dark environments?
- ➜ Do bugs prefer green leaves or rotting sticks?
- ➜ Can your bug learn where to find food?

CHAPTER 2: WHAT CAN WE LEARN FROM BUGS?

Bio-inspiration & Making Bugs

What have scientists learned from bugs?

Bugs have been inspiring science and technology for centuries. Now, new technology allows us to study bugs in greater detail than has been possible before.

Bombardier beetle

If it wasn't for the x-ray synchrotron, scientists would not have seen the incredible explosions this beetle can create inside its abdomen. An x-ray synchrotron is a machine that takes x-rays very fast so you can make a video of the insides of a functioning body. The bombardier beetle uses the explosion as a spray weapon, but by studying it scientists may learn how to make better jet engines or rockets.

Japanese honeybee

If it wasn't for infrared camera technology, scientists would not have discovered that these bees 'cook' hornets at a temperature of within 2° Celsius of what they themselves can survive. By watching how these honeybees work together to defend their hives, scientists are learning how to create digital systems that utilise co-operation and networking.

Dragonfly

If it wasn't for super-high-speed photography, scientists would not have seen the incredible aerial acrobatics the dragonfly is capable of. Nor would they understand how it catches almost 100% of the prey it chases. Scientists are being inspired by the dragonfly's miniature engineering to create high-performance materials, structures, and flying vehicles.

Jewel wasp

If it wasn't for radioactive isotopes, scientists would not have seen how the jewel wasp's venom interacts with the nervous system of a cockroach. Scientists dyed the venom with a radioactive chemical to see where it went. Venom has very specific interactions with the internal systems of organisms. Studying how venom affects these systems has led to the development of medical treatments that could help cure illnesses such as cancer and arthritis.

Orchid mantis

If it wasn't for the combination of ultraviolet reflective white paint and a spectrometer (used to measure light wavelengths), scientists could not have determined how the orchid mantis attracts its prey. For many years, scientists believed it used camouflage to hide from prey. Now we know it lures pollinating insects by looking more attractive than other flowers. The orchid mantis uses sensory exploitation in the way that advertising agencies can persuade you to eat fast food. As proven by the scientists who uncovered the orchid mantis's secret, close observation can reveal the unexpected and challenge assumptions.

Katipō

If it wasn't for DNA-splicing technology, scientists would not be able to reproduce the proteins that are used to make spider silk. By studying spider silk, scientists are discovering new possibilities for construction, medicine, and textiles. Silk, as a biological product, could one day be used as an interface between human nerves and technology in replacement limbs, synthetic eyes, and more.

2.1 Biomimicry

Discuss how bugs have inspired human invention, create your own innovations, and experience the world from a bug's perspective.

2.1.1 Be inspired

Biomimicry is the science of copying nature in form, function, or strategy. Humans have an incredible capacity for critical thinking, so we can be inspired by other organisms to create exciting new technologies and solutions to human problems. There are some helpful internet resources listed in the Appendix, such as AskNature.org.

2.1.2 Experiment

Exploring biomimicry is an opportunity to dive head first into inspiration, invention, and innovation. Just like the scientists who are creating the technology of the future, we can research bugs and find ways of solving problems. The best science attempts to answer questions, so consider the hypothesis first.

Example questions could be:

- Like the orchid mantis, can I look so good that my food comes to me?
- Can I build a machine that can flap like a dragonfly?
- Can I build a rocket that works like the bombardier beetle's abdomen?

Illustration by Weta

Activity

2.1.3 Play with scale

You can also play with scale. Try to copy what bugs do at their tiny size. What apparatus or equipment is needed to re-create a spiderweb? How big would a thread of silk be if a spider was human sized? How heavy would that thread of silk be? How else can playing with scale help us better understand what bugs do?

Activity

2.2 Making bugs

Look closely at a bug, then make a model or puppet bug based on what you see.

Materials:

Playdough or modelling clay	Paper craft material

Optional extras:

Modelling wire	Papier mâché
Lego	Corrugated cardboard
Remote-controlled vehicle	Remote-controlled flying drone

2.2.1 Making models

Make physical 3-D representations of bugs out of playdough, Lego, or papier mâché. The more accurate you try to make your bugs, the more scientific you'll be because you'll be looking for the details of the bug and attempting to understand what you see. Think about proportions like leg length to body, and antennae length. Consider which parts hinge, and which parts are soft, flexible, or solid. Can you build that into your model?
Look closely and ask questions. For instance:

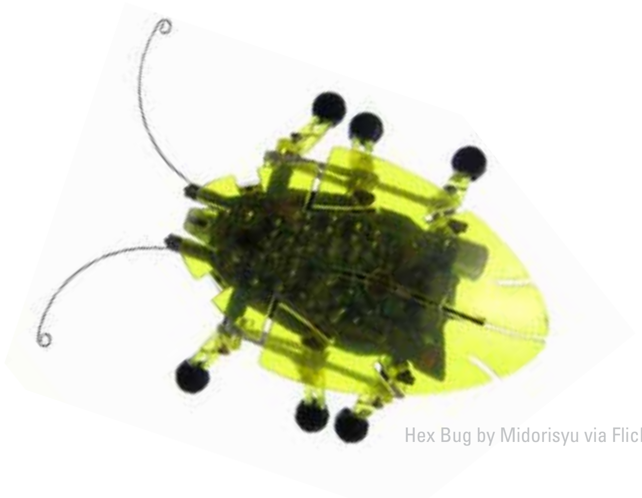
- ➜ How many body parts and how many legs does it have?
- ➜ Are there spikes on the leg?
- ➜ Does the bug have hairs on its body?
- ➜ Are there wing cases?
- ➜ Are there two wings or four? Or any at all?
- ➜ How many different colours is the bug?
- ➜ How many eyes does the bug have?

Rendering by Dane Madgwick. Weta

2.2.3 Making puppets

To create a bug model that's able to move, you could make a bug puppet or attach your model to remote-controlled vehicles or flying drones.

- ➜ What are the limits to building in this way?
- ➜ Do you need to make moving bugs out of lighter materials? Why?
- ➜ What would you use to build a bug robot?
- ➜ How can you test the limits of what the materials can do before you build your puppet or robot?



Hex Bug by Midorisyu via Flickr

2.3 What if we were bugs?

Do some research or use your imagination to get into the mind of a bug, and create a story about its life.

Activity

Materials:

Imagination

Paper and pencil

Optional extras:

Camera

Paint

Costumes

This activity is a creative opportunity to get into the mind of a bug.

Anthropomorphising (giving human characteristics to) bugs can be problematic because we can't assume the way we experience the world is the same as the way bugs do. But it can also lead to interesting discussions about how much you can assume about a bug's point of view compared to a human's. Films like *A Bug's Life* and *Antz* present more fanciful ideas about the lives of bugs. You can decide how realistic you want the hypothetical bug's life to be.

Ant

2.3.1 Imagine the life of a bug

Select a real bug to investigate or make up an imaginary bug and answer the questions below. What other questions about a bug's life could be investigated?

- How long does your bug live for?
- What would your bug's average day be like?
- How long would your bug spend looking for food?
- What would your bug be scared of?
- Who would your bug be friends with?
- Where would your bug make its home?
- Does your bug prefer daytime or night-time? Why?

2.3.2 Create stories

Your stories about your bug can be created in any medium. Write them, draw them, or paint them. Build cardboard dioramas out of shoeboxes. If you have a camera, create animations and record your voice narrating over the top. Design costumes and act out interactions between different students being their preferred bug. What other ways can you think of to tell your bug's story?

Activity

2.4 Indigenous cultural perspectives

Contemporary scientists are not the only people to be inspired by bugs. Humans have always been connected with bugs, and many cultures respect their importance.

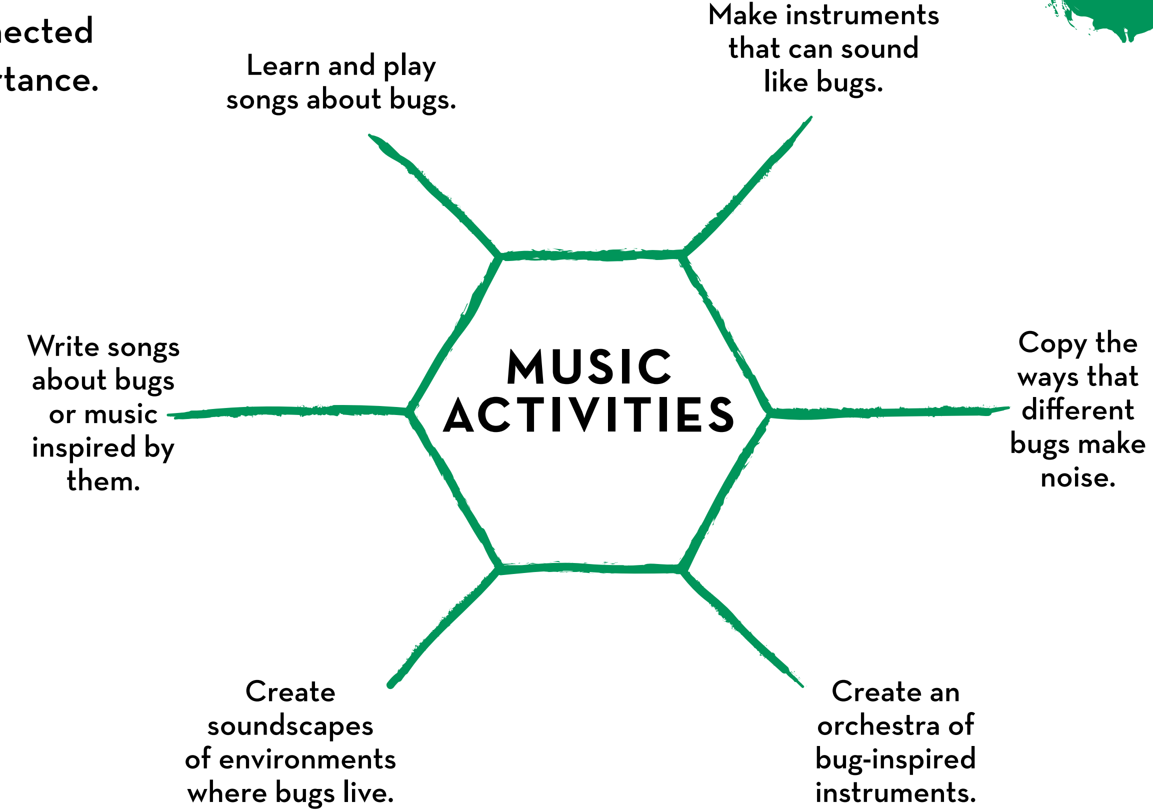
Māori have many songs, stories, and teachings inspired by these awesome creatures. Bugs have also influenced the art of whakairo, woodcarving, which is an important part of Māori culture.

2.4.1 Māori music

Bugs have inspired Māori musical instruments. The pūrerehua, a type of bullroarer, is made from a pointed oval blade carved from hard wood, whale bone, or pounamu (New Zealand jade) and attached to a long tether. When it's swung round the head, it makes a low fluttering sound like a monstrous butterfly. It was used to warn people of danger.

The pūtōrino flute, pictured here, can also be played like a bugle. It's inspired by an intriguing insect called a bag moth. The female bag moth never comes out of her protective silk cocoon. She stays in the trees and waits for the male to find her. She can climb around very slowly, almost like a snail, with her home on her back. Hineraukatauri, goddess of music, is said to have loved her flute so much she climbed into it to live just like a bag moth in its cocoon.

For examples of songs in te reo Māori about insects, see the supporting materials section of the Appendix (4.4.3).

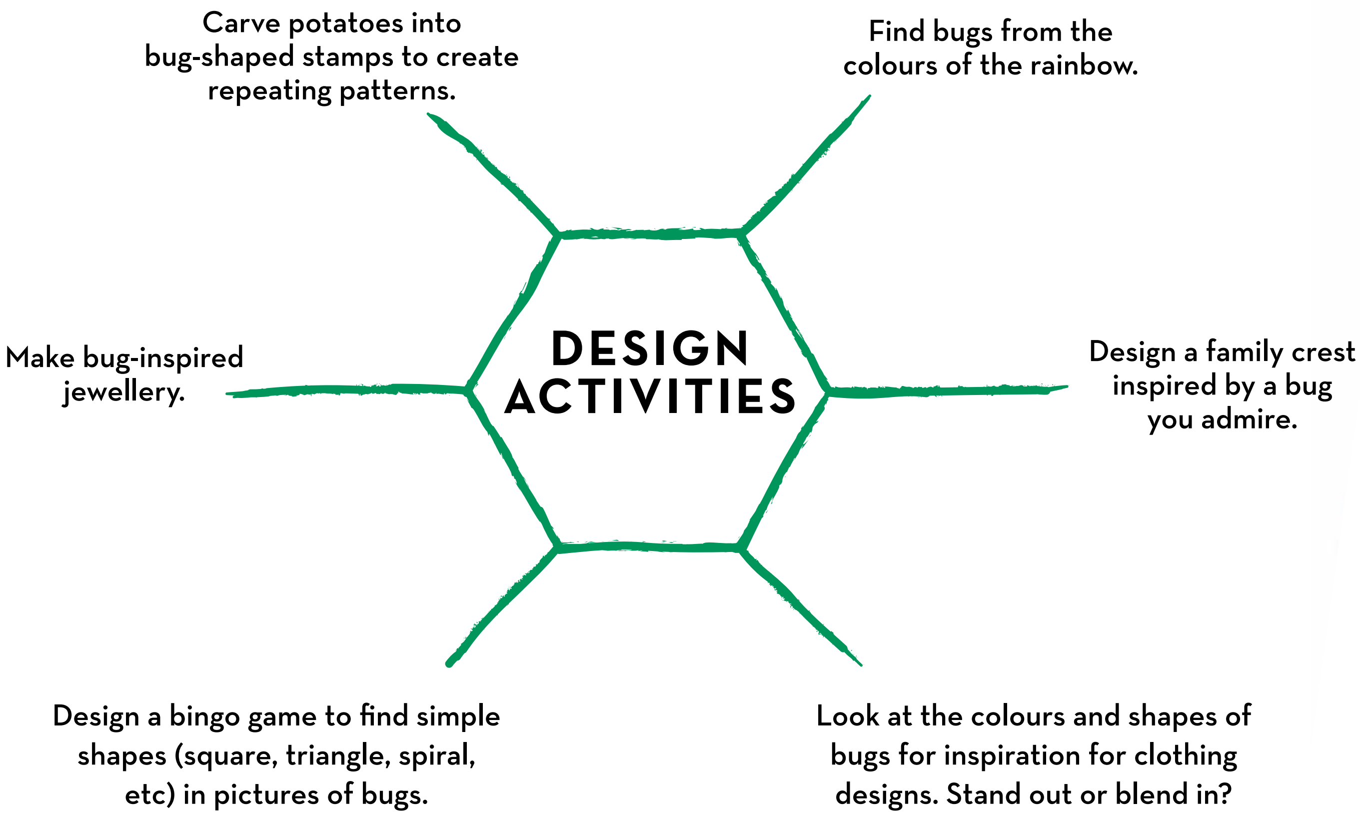


Pūtōrino (bugle flute) maker unknown. 1700-1850, New Zealand, Oldman Collection, gift of the New Zealand Government, 1992

Activity

2.4.2 Māori design

Before Māori had a written language, they used a symbolic language. The symbols were inspired by nature and incorporated into intricate woodcarvings and woven textiles. For example, some carvings reflect spiderwebs or the way insect grubs burrow into wood.



A variety of beetles by Michael Hall. Te Papa

CHAPTER 3: HOW DO WE LIVE WITH BUGS?

Social Impact and Critical Thinking

Activity

Technology allows humans to have unprecedented influence over our environment and the bugs that live there. We must learn to live with bugs because we probably won't survive without them. For example, without pollinators such as bees, beetles, flies, and butterflies, most flowering plants would disappear. That includes food crops such as nuts, fruit, vegetables, and chocolate.

The first two chapters of this resource helped you to explore what bugs do for themselves and what they can do for humans. This chapter will help you to think about what you can do for bugs. It will also give you the resources to ask some of the big, tough questions about how bugs and humans live together. This may encourage a holistic appreciation of how all living things are connected.

In Māori culture, this interconnectedness is called whakapapa and is seen as a sacred bond between everything – from humans to bugs to the land, sea, and sky. See section 1.2.2 for more information about the whakapapa of bugs.

Debate topic suggestions

- Eating bugs
- Insecticides
- Cyborg bugs
- Genetically engineered bugs
- Eradicating mosquitoes

3.1 Informed debate

Debate some of the hot topics about bugs, and launch a campaign to elect the best bug to rule the world.

Below is an example of how to structure an informed debate.

3.1.1 The debate

- Pose a hypothetical question about a subject. Students decide whether to be for or against.
- Ask individuals to rate how they feel about the subject on a scale from 1 to 10, where 1 is strongly disagree and 10 is strongly agree.
- Divide the group into two debating teams.
- Give Team One positive information about the subject.
- Give Team Two negative information about the subject.
- Each team independently brainstorms all the reasons it can think of to support its side of the argument.
- The teams then take turns to try to convince each other of their point of view.
- At the end of the debate, individuals respond on the same strongly disagree–strongly agree scale and determine if there's been any change of opinion.

3.1.2 What if bugs ruled the world?

You could try mounting a presidential-style campaign, in which teams argue that their bug has the best powers to rule the world. Divide the group into more than two teams. Their challenge could be to create posters, convincing arguments, a policy document, and alliances between teams. The teams can do their own research and find their own reasons that one bug would be better than the others.

- ➜ Is it because it is the most helpful to humans? (eg, honeybee)
- ➜ Is it because it is the most powerful? (eg, mosquito, bullet ant)
- ➜ Is it because it has the most legs? (eg, millipede)
- ➜ Is it because it is the most beautiful? (eg, morpho butterfly)
- ➜ It is because it is the best builder and best team player? (eg, termite)

3.2 Bug champions

Think of ways to share your new knowledge about how incredible bugs are.

3.2.1 How can we help bugs?

Through the research and discovery opportunities in this resource, you will have built up a good understanding about what bugs need to survive and thrive. You can now explore ways to help bugs locally, nationally, and internationally.

- ➜ Can you create practical solutions to help bugs?
- ➜ Do bugs need help from humans?
- ➜ Which bugs in particular need help from humans?

3.2.2 Sharing knowledge about bugs

Activity

In Māori culture, the cultivation of kūmara, a kind of sweet potato, was one of the most important and sacred activities. However, farmers often had to defend their crops from the kūmara moth and its grubs. They didn't have a written language to share their wisdom about how to look after kūmara. Instead, they wove their knowledge into whakapapa.

According to the Ngāti Awa tribe, Whānui (the star Vega) is the celestial parent of the kūmara. But Whānui's younger brother, Rongomāui, stole the kūmara as a food source for humans. Whānui was so angry he sent bugs to ravage the kūmara crop as punishment – and they have continued to do so ever since. Some kūmara farmers would plant two fields so they could eat from one and appease Whānui with the other.

Incorporating this wisdom into storytelling ensures it is passed on to future generations. Māori have a holistic understanding of the natural world and acknowledge a space for everything, including the pests that eat their most sacred crop.

- ➜ How would you safeguard your knowledge about bugs?
- ➜ How will you share your knowledge of bugs?
- ➜ Would you rather learn about bugs from a scientific paper or someone telling you a story?
- ➜ How could you combine the best of both?
- ➜ Why is it important to make knowledge accurate and easy to understand?

3.3 Parasites and pests

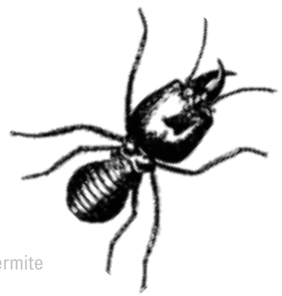
Think about how humans and bugs live together, meet someone who works with bugs, and discover the bugs that share our homes.

Insects and other bugs have adapted to human civilisation. This has put them in conflict with human expansion. Large stores of food attract large numbers of insects, and we build our homes out of timber – the food of many different kinds of insects for millions of years. Then we call them pests and spend huge amounts of money trying to control their numbers.

Worldwide, we use approximately 2.4 billion kilograms of pesticides every year. These are made to control plants, fungi, and animals – including insects. Some pesticides can harm beneficial insects like honeybees as well as pests. Since 2001, there has been a significant increase in the use of neonicotinoid pesticides in the United States, and there are fears it has contributed to the decline of honeybees. Many of the important food crops we eat depend directly or indirectly on pollination by honeybees. How can we protect the food we eat without harming the bugs we need?

Bugs provide many services to keep ecosystems around us functioning. They pollinate the flowers of orchards and food crops. They purify the water we drink. They turn natural waste into nutritious soil.

- ➜ Do we take bugs for granted?
- ➜ How do we benefit from bugs?
- ➜ Are we the parasites?



Termite

Activity

There is a huge wealth of knowledge about the impact of pests and parasites on human lives. Learning about the life cycles of pest and parasite species can give you an appreciation for why they do what they do.

In the references section of the Appendix (4.3), you'll find a website called Pest World for Kids. It's full of free resources – from craft ideas to lesson plans and short informative videos hosted by kids.

3.3.1 Grossology

Parasites and pests are great subjects to teach using 'grossology', which engages kids by using their fascination with things that are icky or disgusting.

3.3.2 Meet an expert

Meet someone who manages insect pests or parasites as part of their job. You could go on a field trip to a farm, or invite a vet to share what they know. What methods of control do they use? Are there bugs that help this person to do their job?

3.3.3 Pests at home

Ask students to survey their homes and bring in evidence of parasites and pests. Design a survey to determine the most common household pests. They could be in the furniture, in the pantry, or on pets.

3.3.4 Pest and parasite PSA

Create a public service announcement (PSA) for the school about the pests and parasites that can be found in the community – head lice, for instance, how to identify head lice, and how to control them.

4.1 Glossary

analogue (noun):	a person or thing seen as comparable to another
arthropod (noun):	an invertebrate animal from the phylum Arthropoda, such as an insect or a spider
bioblitz (noun):	an intense period of biological surveying in an attempt to record all the living species within a habitat
biodiversity (noun):	the variety of life found in a particular habitat
cytolytic (adjective):	dissolves or degenerates cells
endemic (adjective):	belonging exclusively to a particular place
eusocial (adjective):	eusocial organisms have the highest level of organisation, including cooperative care of young and a division of labour
exoskeleton (noun):	a rigid external covering for the body in some invertebrate animals
habitat (noun):	the natural home or environment of an animal, plant, or other organism
indigenous (adjective):	originating or occurring naturally in a particular place; can be indigenous to multiple places
Māori (noun):	the indigenous Polynesian people of New Zealand
mātauranga Māori (noun):	the knowledge and comprehension of everything visible and invisible known to the indigenous Māori people of New Zealand, including their native language
native (adjective):	(of a plant or animal) of indigenous origin or growth
neonicotinoid (noun):	an agricultural insecticide resembling nicotine
neurotoxin (noun):	a poison that acts on the nervous system
parasite (noun):	an organism that lives in or on another organism (its host) and benefits by deriving nutrients at the other's expense
parasitic (adjective):	(of an organism) living as a parasite
pest (noun):	a destructive animal that attacks food or other resources
phylum (noun):	a taxonomic rank, or grouping of related organisms
pūrākau (noun):	te reo Māori name for traditional stories
quadrat (noun):	a rectangular frame used for geographical or ecological survey sampling
radioactive isotope (noun):	an unstable atom that emits energy as radiation or a particle
spectrometer (noun):	an apparatus used to measure a spectrum of intensity
stimulus (noun):	a thing or event that results in a specific functional reaction
synchrotron (noun):	a type of particle accelerator used to propel charged particles to nearly light speed and contain them in well-defined beams
te reo (noun):	literally, the language, short for 'te reo Māori', the language spoken by the indigenous Māori people of New Zealand
waiata (noun):	a Māori song
whakapapa (noun):	te reo Māori word for genealogy, tracing the origins and interconnectedness of all things

4.2 Curriculum links

This resource has activities that are relevant to many curriculum areas, including:

- Science
- Technology
- English
- Arts
- Learning Languages
- Mathematics.

The following three subsections highlight the links to specific regional curriculums.

4.2.1 Te Marautanga o Aotearoa – Ngā hononga ki te Marautanga

Taumata	**Pūtaiao – Te Ao Tūroa**	
1 & 2	Te Rauropi	2. Ka whakawhitiwhiti whakaaro mō ngā mea oreore, ka whakarōpū i runga i ngā rerekētanga.
	Te Taiao	3. Ka mārama haere ki ngā āhuatanga o ia mea oreore e rite ana kia whai oranga ai ia i tōna ake wāhi noho.
Taumata	**Hangarau**	
1 & 2	Te Whakaharatau Hangarau	2. Ka tūhura, ka tautohu i: • ngā hua hangarau whānui • te take me te whakamahi i ngā momo hua
3 & 4	Ngā Āhuatanga o te Hangarau	1. Ka āta whakaaro ki ngā uara me ngā whakapono kua whakamahia, kia mārama ai ngā āhuatanga o te otinga kua puta. Me āta whakaaro ki: • ngā mātāpono hangarau; • te hāngaitanga ki te tangata; • te pāpātanga ki te taiao; • te pānga i ngā wā e heke mai nei.
		2. Ka mārama ki ngā hua o te whakawhitiwhiti kōrero i waenganui i te hapori me te ao whānui.

4.2.2 Te Marautanga o Te Aho Matua – Ngā Paetae Tawhiti

Whakapapa	Mōteatea	Waiata	Karakia	Kaupapa Matua
Te Aitanga-a- Pepeke – Whakapapa	Ngā Mōteatea taketake o ngā iwi	4.4.3 Ngā Waiata Māori	Ngā Karakia taketake o ngā iwi Tuhia ngā karakia hou	Ngā huringa oranga o ngā ngārara Ngā mana tipua tō ngā ngārara Nga hua i ngā ngārara Ngā pānga ki te ao tangata

4.2.3 New Zealand Curriculum

Level	Science Curriculum Links		
1 & 2	Nature of Science	Understanding about science	Appreciate that scientists ask questions about our world that lead to investigations and that open-mindedness is important because there may be more than one explanation.
		Investigating in science	Extend their experiences and personal explanations of the natural world through exploration, play, asking questions, and discussing simple models.
	Living World	Evolution	Recognise that there are lots of different living things in the world and that they can be grouped in different ways.
3	Nature of Science	Understanding about science	Identify ways in which scientists work together and provide evidence to support their ideas.
		Investigating in science	Build on prior experiences, working together to share and examine their own and others' knowledge.
			Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations.
	Living World	Evolution	Explore how the groups of living things we have in the world have changed over long periods of time and appreciate that some living things in New Zealand are quite different from living things in other areas of the world.
4	Nature of Science	Understanding about science	Identify ways in which scientists work together and provide evidence to support their ideas.
		Investigating in science	Build on prior experiences, working together to share and examine their own and others' knowledge.
			Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations.
Level	**Technology Curriculum Links**		
1	Nature of Technology	Characteristics of technology	Understand that technology is purposeful intervention through design.
		Characteristics of technological outcomes	Understand that technological outcomes are products or systems developed by people and have a physical nature and a functional nature.
2	Nature of Technology	Characteristics of technology	Understand that technology both reflects and changes society and the environment and increases people's capability.
		Characteristics of technological outcomes	Understand that technological outcomes are developed through technological practice and have related physical and functional natures.
3	Nature of Technology	Characteristics of technology	Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.
		Characteristics of technological outcomes	Understand that technological outcomes are recognisable as fit for purpose by the relationship between their physical and functional natures.
3	Nature of Technology	Characteristics of technology	Understand how technological development expands human possibilities and how technology draws on knowledge from a wide range of disciplines.
		Characteristics of technological outcomes	Understand that technological outcomes can be interpreted in terms of how they might be used and by whom and that each has a proper function as well as possible alternative functions.

4.3 References

4.3.1 What are bugs?

Arthropod-themed study lessons for kids.
study.com/academy/lesson/characteristics-of-arthropods-lesson-for-kids.html

Basic information about arthropods.
kidzone.ws/animals/arthropod1.htm

Adult-level arthropod information.
en.wikipedia.org/wiki/Arthropod

ARKive.org is a well-regarded biological science–based online encyclopaedia.
arkive.org/invertebrates-terrestrial-and-freshwater

Explanation of how humans benefit from the ecosystem services provided by bugs.
en.wikipedia.org/wiki/Ecosystem_services

Teacher resource to develop small animal investigation in a local environment.
pukeariki.com/Portals/0/pdfs/1-1361711-60_Springs_web_teacher_resource_-_Studying_small_land_animals_FINAL.pdf

Tools for studying live insects.
insects.about.com/od/entomologytools/tp/12toolslive.htm

Learn how to keep live insects as pets.
bugsed.com/rearing_sticks/keeping_insects_tips.html

NatureWatch NZ hosts a fantastic community of naturalists who can answer questions about bugs.
naturewatch.org.nz

Contribute to science – share your observations of nature and connect with other nature lovers around the world.
inaturalist.org

New Zealand–based bug identification website.
landcareresearch.co.nz/resources/identification/animals/bug-id/what-is-this-bug

Spiders from the collection of the National Museum of New Zealand Te Papa Tongarewa.
collections.tepapa.govt.nz/topic/9419

Explanation of geological time and how scientists know how old the world is.
greenforecast.com/what-is-the-geologic-time-scale

428-million-year-old millipede found in Scotland.
nature.com/news/2004/040126/full/news040126-1.html

4.3.2 What can we learn from bugs?

Twenty-minute introductory talk on biomimicry from Janine Benyus, a biomimicry scientist.
ted.com/talks/janine_benyus_biomimicry_in_action?language=en

The Biomimicry Institute empowers people to design nature-inspired solutions to human problems.
biomimicry.org

AskNature.org is a free, online community that helps innovators find inspiration from biology.
asknature.org

Biomimicry Education Network has a free-to-sign up, free-to-download teaching resource all about the science of biomimicry.
ben.biomimicry.net

4.3.3 How do we live with bugs?

Humans eating insects.
en.wikipedia.org/wiki/Entomophagy

A website for kids full of free resources about pests and parasites.
pestworldforkids.org/home/

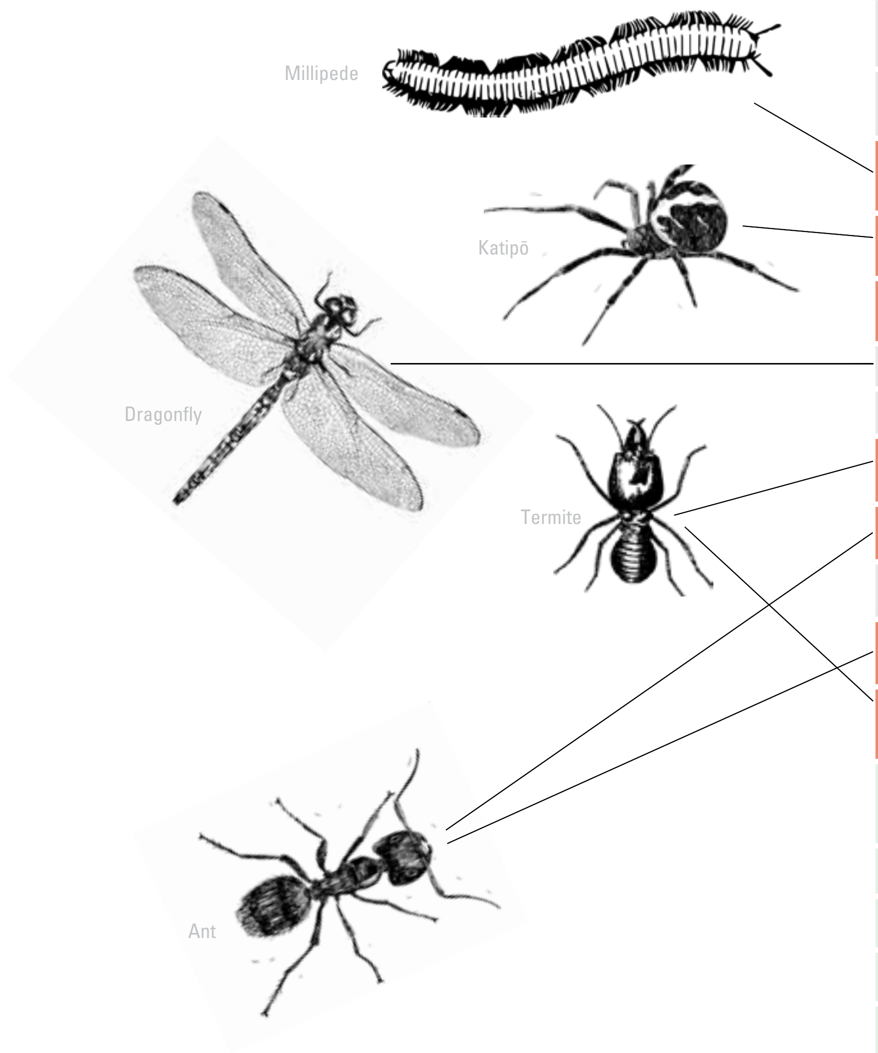
History and information about human pesticide use.
sustainabletable.org/263/pesticides

Discussion about how pesticides affect honeybees.
en.wikipedia.org/wiki/Pesticide_toxicity_to_bees

Pepetuna

4.4 Supporting materials

4.4.1 Evolutionary history of bugs



(BCE = before current era) (M = million years)

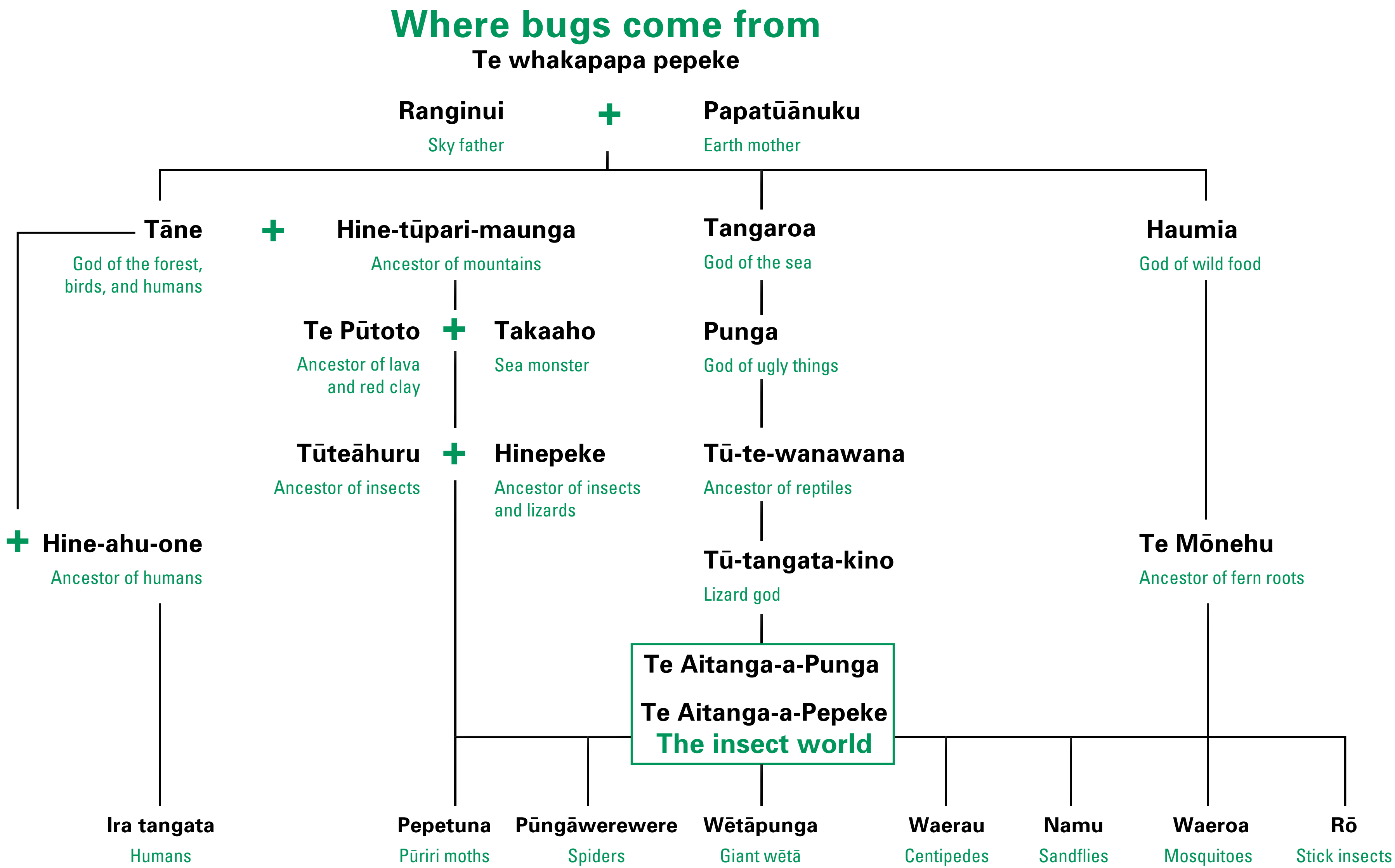
A geological timeline

= Human world = Bug world

Year	Event
4,540 M BCE	Earth forms
542 M BCE	Cambrian explosion (massive, rapid diversification of early organisms)
442 M BCE	First arthropods colonise land
400 M BCE	Origin of winged insects
380 M BCE	Spiders evolve and start using silk
375 M BCE	First vertebrates colonise land
240 M BCE	Origin of the dinosaurs, middle of the Triassic period
100 M BCE	Termites are first eusocial insects to evolve and create fortified structures
99 M BCE	Ants develop advanced colonial societies
66 M BCE	Most dinosaurs become extinct, end of the Cretaceous period
50 M BCE	Ants begin animal husbandry of honeydew-producing aphids
25 M BCE	Termites begin farming fungus (first animals to grow their own food)
200,000 BCE	The first modern human (*Homo sapiens*), our common ancestor
11,500 BCE	Agricultural cultivation of rice starts in China
6,500 BCE	Jericho built – one of the world's oldest cities
4,500 BCE	Egyptians keep domesticated bees and harvest their honey
3,630 BCE	Humans start using cultivated silk
Year 0	
1903 CE	Humans succeed at powered flight

4.4.2 Te whakapapa pepeke: A genealogy of bugs from a Māori cultural perspective

This whakapapa (genealogy) traces the origins and interconnectedness of humans and bugs from a Māori perspective.



4.4.3 Waiata Mäori – Songs about bugs sung in te reo Mäori

Hineraukatauri (Mäori goddess of music)

youtube.com/watch?v=UVzPpIBC3wA

A song about the daughter of Hineraukatauri.

Kihikihi (cicada)

youtube.com/watch?v=gSer1Y87s90

Mäori recognise different varieties of cicada by the sounds they make.

Püngäwerewere (spider)

youtube.com/watch?v=TdZ7_fa1n4Y

Rob Ruha is a contemporary Mäori folk musician. This version is performed by The Matua Twins at their school.

Pükäwerewere (spider)

youtube.com/watch?v=eQ3v31CFpKw

There are many regional variations of this song in te reo Mäori.
This version has translations for the lyrics, which describe how spiders build their webs.

Pürerehua (butterfly)

folksong.org.nz/purerehua/index.html

Link contains lyrics and sheet music. A Mäori instrument called a pürerehua can be heard at the very start of the song.

Tarakihi (cicada)

folksong.org.nz/tarakihi/

This traditional waiata reflects on the cicada as a symbol of strength for Mäori people.
The link contains background information and translations of the lyrics.

SEE THE WORLD THE BUGS BUILT