

Teacher Notes

Themes

- Soil and soil organisms
- Relationships between microbes, plants and animals
- Life cycle of nematodes

Key learning outcomes

- Learn about the size scales of different forms of life, and how very small living things can help very large ones
- Understand the concept of symbiosis (living together)
- Recognise how living things prey on some creatures while also cooperating with others
- Learn how living things communicate without a spoken language
- Understand that healthy soil contains a myriad of creatures, air and water, and is not just uniform 'dirt'

Key curriculum areas

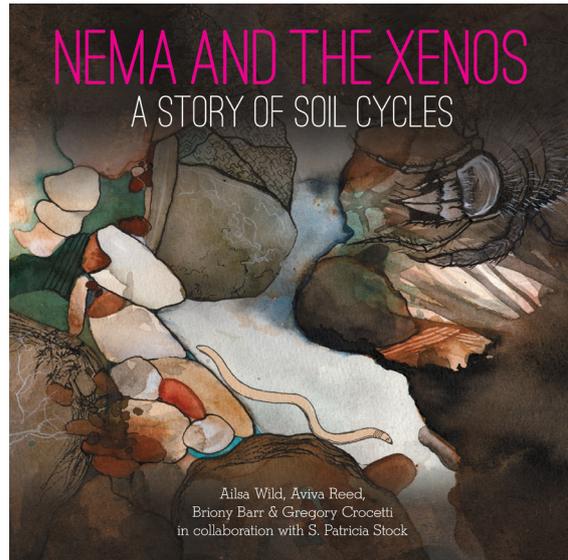
- English: Language, literature, literacy
- Science: Biological sciences, Earth and space sciences
- The Arts: Making, responding
- Cross Curriculum Priority – Sustainability: Systems, world views, futures

Publication details

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Nema and the Xenos

A Story of Soil Cycles

Ailsa Wild, Aviva Reed, Briony Barr and Gregory Crocetti, in collaboration with S. Patricia Stock

This book tells the tale of Nema the nematode – and the deadly bacteria that hitchhike inside her – in her mission to answer a distress signal sent out by tree roots being attacked by a hungry grub.

Nema and the Xenos is the third title in the Small Friends Books series, which uses beautiful art and engaging stories to introduce children to the world of microbes and the amazing symbiotic partnerships they form with animals and plants.

Readers aged 8–12, teachers, librarians and parents

Co-published by CSIRO Publishing and Scale Free Network



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About the creators

Nema and the Xenos is the creation of a team of people who work together, just like the characters in the story, to accomplish more than they could do on their own.

The story is written by Ailsa Wild, a writer-performer who creates fiction, non-fiction and physical theatre. She also wrote *The Squid, the Vibrio & the Moon* and *Zobi and the Zoox*, the first two illustrated science-adventure stories in the Small Friends Books series.

The enchanting illustrations are made by Aviva Reed, an artist and scientist who loves combining ideas and exploring concepts from multiple perspectives. She also illustrated the first two Small Friends books.

Dr Gregory Crocetti and Briony Barr, who are collaborators in the art-science collective Scale Free Network, co-author and co-publish the Small Friends Books series. The final member of the team is S. Patricia Stock, a professor at the University of Arizona, who studies the interactions between nematodes, microbes and their insect hosts.

“I love being part of this deeply collaborative team,” Ailsa says. “I take the lead on the storytelling, but I really enjoy the part of the process where I’m led by other experts in the group. Gregory guides us through the scientific research, and Briony works closely with him designing a storyboard so each page reflects the story and real science. We get feedback from scientists and sometimes we’ve needed to change the story completely because my first plot wasn’t actually possible.”

“Aviva, Briony, Gregory and I often meet for hours (or days!) to go through each draft together and talk through the ideas. It’s amazing to be part of creating something together, which is far more layered and beautiful and scientifically rigorous than I could ever do if I was working alone.”

Aviva’s favourite part of the illustration process is “the eyes-closed part, the bit where I have done the research and try and put it all together in my mind’s eye, using my imagination.”

“Every work I make, I visualise the image in my mind before I start,” Aviva says. “I seek to visualise the composition and palette before I start to try and capture a story.”

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Pre-reading activity: Soil discovery

Equipment needed: shovel or spade, bucket

Take students outside and find a place where you can dig up a shovelful of soil. Allow the students to get their hands dirty and feel the textures of the soil. What can they see? What can they smell? How does it feel in their hands? Is it wet or dry? Sticky or crumbly? Can they shape it into a ball?

Soil is made of different mixtures of sand, clay and silt, along with dead and living creatures. It is formed in layers, called horizons. The topsoil contains the most living creatures and organic matter: dead leaves, worms and insects might be visible. Invisible creatures (to the students' eyes) will include fungi, bacteria and many other living things, such as nematodes – the main characters in the story. If you have a hand lens, the students may see some of the smaller living creatures in the topsoil.

Depending on your location, your shovel may yield only topsoil, or it may also contain some of the next horizon, called subsoil, if the topsoil layer is very thin. The subsoil also contains a mixture of sand, clay and silt, but has less organic matter. If you have time, you could also dig a shovelful of soil from different places in the school yard to see if the soil varies from place to place.

Once you have finished looking at the soil, allow each student to place a handful into the bucket. Keep the bucket of soil for the later science activities.

Questions to discuss

1. Thinking about soil

Key curriculum areas – Science: Biological sciences, Earth and space sciences; Cross Curriculum Priority – Sustainability

As a starting point for thinking about and discussing soil, ask students to break up into small groups to write down some ideas in response to these questions. They can reflect on their pre-reading 'Soil discovery' activity to help them come up with their ideas.

- Where is soil found?
- What is soil made of?
- Where does soil come from?
- What creatures live in soil?
- What can you do with soil?

Then come back together as a class to discuss. Some good background information about soil formation for teachers can be found at <https://www.soils4teachers.org/files/s4t/lessons/soils-overview-for-teachers-2017.pdf>.

2. Soil means different things to different people

Key curriculum areas – Science: Biological sciences, Earth and space sciences; Cross Curriculum Priority – Sustainability

Soil can mean very different things to the people and creatures who use it. In this discussion-based group activity, students talk about and try to match up the different views of soil given.

Print enough copies of the tables overleaf for students to share in groups of three to four. (Note that the answers are deliberately not in the correct order in the tables provided.) Have students cut along the lines and then work together to discuss and rearrange the pieces to try and match up the people and creatures with the definitions of how they see soil.

When they have finished, compare the different groups and see if everyone has the same answers. Can there be more than one correct answer? Do some of the definitions of soil match more than one type of person or creature?

Continue the discussion by asking if the students can think of any other people or living things that see the soil in different ways.

- **Extension discussion question:** If soil is lost or degraded through overharvesting, overuse of fertilisers and pesticides, land clearing, erosion or contamination, what effects might this have on each view of the soil?

The answers are below:

- Farmers and gardeners see soil as something that is nurtured to grow crops and feed livestock
- Engineers see soil as a foundation on which to build
- Hydrologists see soil as a course for rivers and a source of drinking water
- Children see soil as an ingredient for a mud pie
- Climate change scientists see soil as a source and sink for most of the world's carbon
- Biologists see soil as a rich habitat, teeming with life
- Parents see soil as something they need to clean up afterwards
- Bacteria, fungi and other soil-dwelling creatures see soil as a home
- Plants see soil as a source of support, water and minerals

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Farmers and gardeners see soil as:

Engineers see soil as:

Hydrologists see soil as:

Children see soil as:

Climate change scientists see soil as:

Biologists see soil as:

Parents see soil as:

Bacteria, fungi and other soil-dwelling creatures see soil as:

Plants see soil as:

a course for rivers and a source of drinking water

a rich habitat, teeming with life

something that is nurtured to grow crops and feed livestock

something they need to clean up afterwards

a foundation on which to build

a home

a source and sink for most of the world's carbon

an ingredient for a mud pie

a source of support, water and minerals

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3. Symbiosis Q&A

Key curriculum areas – Science: Biological sciences

One of the main themes in the book is the symbiotic relationship between Nema the nematode and the Xenos – the bacteria that live inside the nematodes. There are different types of symbiotic relationship, depending on whether both species benefit or only one.

- Q.** Why do the bacteria need to live inside the nematode?
- A.** Inside the nematode, the bacteria find a safe home protected from other predators. The nematode takes the bacteria where they need to go – inside the body of the grub. The bacteria also rely on the next generation of nematodes to carry them away from one dead, used-up grub to the next live grub.
- Q.** Why does the nematode need to carry the bacteria?
- A.** The bacteria produce chemicals that help nematodes kill and decompose (break down) the grub. This provides food to the nematodes, allowing them to reproduce and multiply. The bacteria also produce chemicals that create a shield around the grub, making it a safe place for the nematodes to reproduce.
- Q.** Is this relationship benefiting both? What type of symbiosis is this classified as?
- A.** Yes, both species benefit. It is a type of symbiosis called mutualism.
- Q.** Are there any other examples of mutualism in the story?
- A.** Yes. Nema the nematode, and the Xenos inside Nema, have a symbiotic relationship with the tree. This is an example of mutualism, because both species benefit. The tree sends out a chemical signal that helps the nematodes locate a host (the grub) to reproduce inside, and in return, the nematodes help protect the tree from the hungry grub.
- Q.** Another type of symbiosis is known as commensalism. This means that one species benefits, but the other is neither hurt nor particularly helped. For example, one creature may use another one for transportation or for housing. Can you think of any examples?
- A.** Examples include hermit crabs using old shells to protect their bodies, birds living in tree hollows, spiders building webs on plants.
- Q.** A third type of symbiosis is known as parasitism. This means that one species (called a parasite) benefits, while the second species, called the host, is harmed or sometimes even killed. Is there an example of parasitism in the story?
- A.** Yes. Working together, the nematodes and the Xeno bacteria enter and kill the grub. In this example the nematode is the parasite and the grub is the host.

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- Q.** Can you think of any other examples of parasitism? (Hint: You may have had parasites living on your head at some stage in your life, and your dog or cat may also have some!)
- A.** Head lice are parasites that live on humans. They won't kill you, but they do suck your blood. Your dog or cat may have fleas or ticks. There are many other examples of parasitism.

4. Looking at emotive language

Key curriculum areas – English; Cross Curriculum Priority – Sustainability

The book uses emotive language to convey how the characters might be feeling and behaving, as if they were able to have feelings and behave in a similar way to humans. Here are some examples.

“A tree stands, waist deep in earth, its tender roots in agony.”

“Algae thrive here, happily making sugar from the light.”

“Nema’s eggs hatch and the grub begins to fill with ravenous baby nematodes. ‘Now you must feast on us,’ say the Xenos. The nematodes pause, unsure.”

“The bacteria ignore her. But a tip of friendly white fungus curves out of the structure.”

- Q.** What are the emotive words used in these sentences that convey feelings or behaviours that you might think of as human?
- A.** Answers will vary in the discussion. For instance in the first example, the tree has a “waist”, which is a term used for the human body. “Tender” roots imply they are easily damaged and need to be carefully nurtured, like a baby. “Agony” implies a great deal of pain and makes the reader feel sorry for the tree.
- Q.** Why do the authors use this type of emotive language in a non-fiction science book?
- A.** Answers will vary in the discussion, but will likely include the theme of making the characters seem more human to the reader, which makes the reader care about the characters and be more interested in the story. Hopefully, it also makes the reader care more about these plants and creatures in real life. This leads to people taking more care of the natural environment, once they understand how important each living thing is, and how important the interactions between them are to enable a healthy, sustainable environment for us all.

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5. Extension questions to research

Key curriculum areas – Science: Biological sciences, Earth and space sciences; Cross Curriculum Priority – Sustainability

Fertile soil is soil that contains lots of nutrients to help plants grow and thrive. Most of the nutrients in fertile soil come from the decay of dead plants and animals.

- Why does soil quickly become less fertile if it is used to grow crops that are repeatedly harvested or cleared of vegetation?
- What are some of the problems that might occur when farmers use large amounts of fertiliser to make up for the lack of fertile soil? (Hint: Think beyond the farm into the wider environment. Where does the fertiliser eventually end up?)
- What are some ways to increase the fertility of soil?



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Quiz questions

1. The four main characters in the story are drawn below.

Can you number them from smallest to biggest in size? (1 = smallest, 4 = biggest)



Grub



Nema



Tree



Xenos

2. Where does the story take place?

3. What is the problem at the start of the story?

4. How is the problem solved?

5. How do the nematodes know where to go?

6. How do the Xenos help the nematodes?

Quiz answers

1. The four main characters – from smallest to biggest – are:
 - Xenos
 - Nema
 - Grub
 - Tree
2. The story takes place underground/in the soil/near the tree's roots.
3. At the start of the story, one of the tree's roots is under attack from a grub (page 3).
4. Nema and the Xenos find the grub, and then they kill it (page 24).
5. Nema follows the chemical pain signals released from the tree (pages 3–4).
6. The Xenos help the nematodes in three main ways:
 - They disarm the grub's immune system and kill the grub (page 23).
 - They create a toxic defensive shield around the grub (page 24).
 - They help decompose (break apart) the grub's insides, which feeds the nematodes. The bacteria themselves also become food for the nematodes! (page 25).

Activities

Writing activity 1

Re-tell the story from the perspective of either the tree or the baby grub that is under attack from the nematodes.

Writing activity 2

Close your eyes and imagine you are a tiny creature living in the soil. Write and illustrate a short story, poem or comic about your new tiny life that describes the following in as much detail as possible:

- What can you see?
- What can you smell?
- What can you hear?
- What can you touch?
- What can you taste?



Art activity 1

Create a scene from the story using modelling clay or plasticine.

This could include parts of the soil (such as sand particles), plant roots, fungi and other creatures from the story.

Use the models to recreate the life cycle of Nema and the Xenos that live inside her.

Art activity 2

Draw a picture of your favourite moment from the story, or write and illustrate a short comic showing the most exciting part of the story.



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Science activities: Looking more closely at soil

Use a range of tools to more closely observe characteristics of the soil the students collected in the pre-reading activity. For instance:

- Look more closely at small samples of soil using magnifying glasses or stereo microscopes.
- Use gauze fabric, a funnel and water to separate the different particles of soil
 - silt and clay particles should wash through
 - sand particles and organic matter will be trapped on top of the fabric.
- Add soil to a jug of water to separate different materials
 - organic material is more likely to float
 - minerals should sink immediately.
- Use hammers or other tools to crush soil
 - Some elements crush differently to others (e.g. clay is very soft, sand particles are more difficult to crush).

Ask students to draw or describe the different observations from these activities. Is their soil sample more clay-like, or is it very sandy? Is it a good mixture of all three particles? (This type of soil is ideal for most plants, and is known as loam.)

Students can read page 35 'Soil is the skin of the Earth' and answer the following comprehension questions to help them explain their observations from the activities.

- Q.** What are the three mineral particles found in soil?
- A.** Clay, silt and sand.
- Q.** Which is the biggest particle, and which is the smallest?
- A.** Sand is the biggest. Clay is the smallest.
- Q.** Where do these particles come from originally?
- A.** From larger rocks that have broken down by weathering (wearing away).
- Q.** True or false: physical weathering is caused by acids and other chemicals.
- A.** False. Physical weathering is caused by wind, rain, snow, sun and cold. Acids and other chemicals are the basis of biological and chemical weathering.



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Australian Curriculum Links

Year level	Learning area: science	Other learning areas
Year 3/4	<p>Science Understanding: Biological sciences</p> <ul style="list-style-type: none"> Living things can be grouped on the basis of observable features and can be distinguished from non-living things (ACSSU044) Living things have life cycles (ACSSU072) <p>Science Understanding: Earth and space sciences</p> <ul style="list-style-type: none"> Earth's surface changes over time as a result of natural processes and human activity (ACSSU075) <p>Science as a Human Endeavour</p> <ul style="list-style-type: none"> Science knowledge helps people to understand the effect of their actions (ACSHE051, ACSHE062) <p>Science Inquiry Skills</p> <ul style="list-style-type: none"> With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (AC SIS054, AC SIS065) Represent and communicate observations, ideas and findings using formal and informal representations (AC SIS060, AC SIS071) 	<p>English</p> <ul style="list-style-type: none"> Discuss texts in which characters, events and settings are portrayed in different ways, and speculate on the authors' reasons (ACELT1594) Create literary texts that explore students' own experiences and imagining (ACELT1607) <p>The Arts: Visual Arts</p> <ul style="list-style-type: none"> Use materials, techniques and processes to explore visual conventions when making artworks (ACAVAM111) Present artworks and describe how they have used visual conventions to represent their ideas (ACAVAM112) <p>Cross Curriculum priority: Sustainability</p> <p>OI.1 The biosphere is a dynamic system providing conditions that sustain life on Earth.</p> <p>OI.2 All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.</p> <p>OI.3 Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems.</p> <p>OI.4 World views that recognise the dependence of living things on healthy ecosystems, and value diversity and social justice, are essential for achieving sustainability.</p> <p>OI.7 Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments.</p>
Year 5/6	<p>Science Understanding: Biological sciences</p> <ul style="list-style-type: none"> Living things have structural features and adaptations that help them to survive in their environment (ACSSU043) The growth and survival of living things are affected by physical conditions of their environment (ACSSU094) Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096) <p>Science as a Human Endeavour</p> <ul style="list-style-type: none"> Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE083, ACSHE100) <p>Science Inquiry Skills</p> <ul style="list-style-type: none"> Identify, plan and apply the elements of scientific investigations to answer questions and solve problems using equipment and materials safely and identifying potential risks (AC SIS086, AC SIS103) 	<p>English</p> <ul style="list-style-type: none"> Understand, interpret and experiment with sound devices and imagery, including simile, metaphor and personification, in narratives, shape poetry, songs, anthems and odes (ACELT1611) Create literary texts using realistic and fantasy settings and characters that draw on the worlds represented in texts students have experienced (ACELT1612) <p>The Arts: Visual Arts</p> <ul style="list-style-type: none"> Develop and apply techniques and processes when making their artworks (ACAVAM115) <p>Cross Curriculum priority: Sustainability</p> <p>OI.1 The biosphere is a dynamic system providing conditions that sustain life on Earth.</p> <p>OI.2 All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.</p> <p>OI.3 Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems.</p> <p>OI.4 World views that recognise the dependence of living things on healthy ecosystems, and value diversity and social justice, are essential for achieving sustainability.</p> <p>OI.7 Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments.</p>

Related books from CSIRO Publishing

The Squid, the Vibrio & the Moon (2019)

Zobi and the Zoox (2018)