Australian National Botanic Gardens

Lesson Plan

Module 4

Seeds

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past, present and emerging.

Plant Science Learning Hub

Students need a space to learn that is fun and rewarding. The Australian National Botanic Gardens has developed a Plant Science Learning Hub that aims to inspire and engage students in plant science and the stories surrounding Australian flora. With clear links to the Australian Curriculum for school years four to six, the Plant Science Learning Hub will provide a valuable resource for students and educators.

- Plant Life Cycles
- Plant Structure
- Pollination
- **Seeds**

This series provides educators with authoritative plant science content that has a uniquely Australian perspective. The Gardens manages globally significant scientific collections of living plants and herbarium specimens of Australian native flora. We provide educational experiences for students from pre-primary to tertiary levels, leveraging our scientific collections, participation in national and international conservation projects and outreach programs to engage the community in valuing, conserving and appreciating Australia's diverse plant heritage.

Module learning objectives

The following learning objectives apply to the Seeds Module.

1. Understand the role of seed banks in conserving plant species.
2. Identify features that assist in different seed dispersal techniques.
3. Explore the anatomy of a seed and discover how they are adapted to different environmental germination triggers.

Each lesson within the lesson plans and the field kits has individual learning intentions appropriate to the activity.

Contents

Lesson Three: Seeds and their needs

LEARNING INTENTIONS

Students will be able to:

- Understand seed viability and what scientists look for to determine if a seed will germinate.
- Understand what seed germination is and what can affect it.
- Explore germination strategies and how changes to the requirements of a plant can affect germination.

CURRICULUM LINKS

This material provides opportunities for students to engage in the following Australian Curriculum **(Version 9)** content descriptions:

Science understanding

AC9S5U01 Examine how particular structural features and behaviours of living things enable their survival in specific habitats (Year 5)

AC9S6U01 Investigate the physical conditions of a habitat and analyse how the growth and survival of living things is affected by changing physical conditions (Year 6)

Science as a human endeavour

AC9S4H01 Examine how people use data to develop scientific explanations (Year 4)

AC9S4H02 Consider how people use scientific explanations to meet a need or solve a problem (Year 4)

AC9S5H01 Examine why advances in science are often the result of collaboration or build on the work of others (Year 5)

AC9S5H02 Investigate how scientific knowledge is used by individuals and communities to identify problems, consider responses and make decisions (Year 5)

AC9S6H01 Examine why advances in science are often the result of collaboration or build on the work of others (Year 6)

AC9S6H02 Investigate how scientific knowledge is used by individuals and communities to identify problems, consider responses and make decisions (Year 6)

Science inquiry

AC9S4I01 Pose questions to explore observed patterns and relationships and make predictions based on observations (Year 4)

AC9S4I02 Use provided scaffolds to plan and conduct investigations to answer questions or test predictions, including identifying the elements of fair tests, and considering the safe use of materials and equipment (Year 4)

AC9S4I03 Follow procedures to make and record observations, including making formal measurements using familiar scaled instruments and using digital tools as appropriate (Year 4)

AC9S4I04 Construct and use representations, including tables, simple column graphs and visual or physical models, to organise data and information, show simple relationships and identify patterns (Year 4)

AC9S4I05 Compare findings with those of others, consider if investigations were fair, identify questions for further investigation and draw conclusions (Year 4)

Seeds

AC9S4I06 Write and create texts to communicate findings and ideas for identified purposes and audiences, using scientific vocabulary and digital tools as appropriate (Year 4)

AC9S5I01 Pose investigable questions to identify patterns and test relationships and make reasoned predictions (Year 5)

AC9S5I02 Plan and conduct repeatable investigations to answer questions, including, as appropriate, deciding the variables to be changed, measured and controlled in fair tests; describing potential risks; planning for the safe use of equipment and materials; and identifying required permissions to conduct investigations on Country/Place (Year 5)

AC9S5I03 Use equipment to observe, measure and record data with reasonable precision, using digital tools as appropriate (Year 5)

AC9S5I04 Construct and use appropriate representations, including tables, graphs and visual or physical models, to organise and process data and information and describe patterns, trends and relationships (Year 5)

AC9S5I05 Compare methods and findings with those of others, recognise possible sources of error, pose questions for further investigation and select evidence to draw reasoned conclusions (Year 5)

AC9S5I06 Write and create texts to communicate ideas and findings for specific purposes and audiences, including selection of language features, using digital tools as appropriate (Year 5)

AC9S6I01 Pose investigable questions to identify patterns and test relationships and make reasoned predictions (Year 6)

AC9S6I02 Plan and conduct repeatable investigations to answer questions including, as appropriate, deciding the variables to be changed, measured and controlled in fair tests; describing potential risks; planning for the safe use of equipment and materials; and identifying required permissions to conduct investigations on Country/Place (Year 6)

AC9S6I03 Use equipment to observe, measure and record data with reasonable precision, using digital tools as appropriate (Year 6)

AC9S6I04 Construct and use appropriate representations, including tables, graphs and visual or physical models, to organise and process data and information and describe patterns, trends and relationships (Year 6)

AC9S6I05 Compare methods and findings with those of others, recognise possible sources of error, pose questions for further investigation and select evidence to draw reasoned conclusions (Year 6)

AC9S6I06 Write and create texts to communicate ideas and findings for specific purposes and audiences, including selection of language features, using digital tools as appropriate (Year 6)

CONTENT INFORMATION

Seed banks are collections of stored seeds that can be naturally occurring or man-made. Seed banks act as a 'back-up' storage of seeds, which ensures that plants persist in the environment and do not go extinct. Natural seed banks allow plants to regenerate when all above ground vegetation is lost e.g. after a bushfire. Conservation seed banks allow us to re-grow species in case of extinction. Seed banks store seeds much like financial banks accumulate money, and 'depositing' seeds in the seed bank can act as an investment in the future of the plant species and the ecosystem as a whole.

Conservation seed banks allow us to re-grow species in case of extinction.
Image: ©ANBG, 2023

CONSERVATION SEED BANKS

Conservation seed banks are managed by seed scientists who collect, study and store seeds to safeguard the future of plant species. Successful seed storage relies on maintaining constant temperature, moisture and light levels. Seed banks use temperature controlled, and humidity controlled drying rooms to process seeds collected in the field to ensure they are stable for storage. Large freezers set to sub-zero temperatures are used for the long-term storage of seeds.

Seed scientists around the world investigate the most effective ways of collecting, treating, storing and germinating different seeds. They find the best ways to store seeds, ensuring that they remain **viable** for many years but do not germinate while in storage. Discovering the germination conditions required by thousands of plant species is not a simple task, and sometimes it takes years to 'crack the code' of just one species! To do this, seed scientists check the **fill** and **viability** of the seeds and then trial different **pre-treatment** methods.

Seed banks have the capacity to germinate and reintroduce plants back into the wild or use them for research into future foods or medicines. Up to 40% of global plant species are at risk of becoming extinct due to the impacts of land clearing, invasive species and climate change, so seed banks are crucial to safeguarding the Earth's biodiversity.

The National Seed Bank is located at the Australian National Botanic Gardens.

Image: ©ANBG, 2022

Check seed fill and viability

→ Seed fill: seed samples are x-rayed to determine how many are 'full' (have intact endosperms and embryos).

→ Seed viability: Even when full, seeds might not be viable. Tetrazolium chloride stains live embryos red while non-viable embryos do not stain.

↓

Investigate germination requirements (at least 75% germination success)

→ Germination conditions: mimic what seeds experience in nature.

→ Related species: existing germination protocols for related species are trialled for seeds being investigated; if unsuccessful, other pre-treatments are trialled.

→ Pre-treatments: warm or cold stratification, fire-related (smoke and heat), acid scarification or scalpel chipping, light/dark regimes, constant/alternating temperatures.

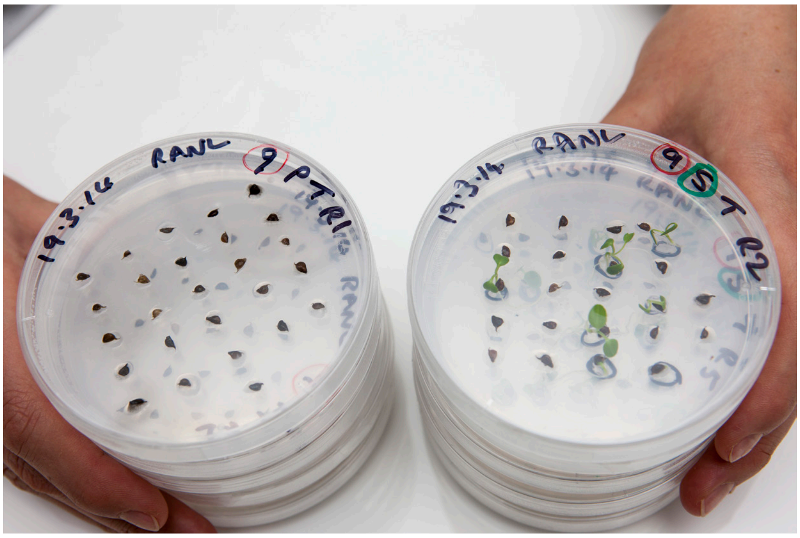
THE NATIONAL SEED BANK

The National Seed Bank

The Gardens' National Seed Bank (NSB) in Canberra plays a critical role in the conservation of native plants on a national and international scale. The NSB has four main functions:

1. **Conservation**: to act as a long-term seed bank, particularly for the storage of rare and threatened flora.
2. **Research**: to conduct research into the biology and ecology of Australian native seed.
3. **Propagation**: to supply seed to produce seedlings for the Gardens' living collections.
4. **Supply**: to supply seed to research organisations through the plant release program.

The NSB has been collecting native seed since the 1960s and houses more than 8,000 individual seed collections, representing more than 4,000 plant taxa and 139 threatened species. The NSB collects seed from target environments including alpine, subalpine and grassland regions near the Australian Capital Territory. Between 2007 and 2012, NSB seed scientists and researchers from the Australian National University (ANU) worked together to 'bank' 451 alpine seed collections from 148 species. The NSB's drying room remains at a constant 15°C and 15% relative humidity and the storage freezers at -21°C. Stored in these conditions, the NSB's seed collections can remain viable for hundreds of years.



Seeds are tested for viability at the National Seed Bank located at the Australian National Botanic Gardens.

Image: ©ANBG, 2022

GERMINATION

Germination is the first stage in the process of a seed becoming a plant. Chemicals contained in the seed coat can be triggered by certain environmental conditions and ensure that the seed only germinates when conditions are favourable. When those conditions are detected the seed coat absorbs water, causing it to crack open and expose the **embryonic** root and shoot inside. This allows the shoot to grow towards the direction of the sunlight and emerge as a seedling, feeding off the **endosperm** until it grows leaves that allow it to produce its own food through **photosynthesis**. Seeds do not necessarily germinate immediately after they have been dispersed, as they have different **germination strategies** and require different **germination triggers**.

Germination strategies

A common **germination strategy** is **dormancy**. The seed remains 'asleep' and cannot germinate until it experiences the right conditions to **alleviate** its dormancy. This strategy allows a seed to delay germination until it can 'sense' that conditions are optimal for seedling growth.

There are different kinds of seed dormancy.

- **Exogenous dormancy** is dictated by conditions outside of the plant embryo and includes physical, mechanical and chemical dormancy.
- **Endogenous dormancy** occurs because of conditions within the embryo and includes physiological, morphological and combined dormancy.

Dormancy is a common germination strategy amongst species that inhabit harsh or unpredictable environments. For example, many alpine species have a dormancy which is only alleviated after exposure to several weeks of cold temperatures. This ensures that seeds germinate after winter when conditions are less harsh. Dormancy prevents seeds from germinating until conditions are suitable not just for germination, but also for a seedling to grow.

While seeds wait to experience the conditions required to alleviate their dormancy they are stored either in the plant itself or in the soil.

- When dormant seeds are stored in the plant it is called **serotiny**, which is observed in some *Banksia* species. This creates **aerial seed banks** where many seeds are stored in cones or pods above the ground.
- When dormant seeds are stored in soil it is called **geospory**, which is observed in many Australian species. In this case the soil acts as a seed bank, storing seeds from different species together.

Some species of *Banksia* store their seeds in their cones, creating 'aerial seed banks'. Image: A.Lyne©ANBG, 1993

Alternative germination strategies amongst native alpine species include **non-dormancy**, where germination tends to be immediate, and **staggered germination**, where there are some dormant and some non-dormant seeds produced by a plant, allowing germination to occur at different intervals from the time of dispersal. These different strategies allow plants to hedge their bets in terms of survival in the environmental conditions.

GERMINATION TRIGGERS

Germination triggers are physical or chemical conditions or events that signal to a seed to begin germinating. Different seeds have different germination triggers, such as:

- light levels
- oxygen levels
- soil moisture
- fire/smoke
- scarification or
- temperature.

These are explored in more detail in the following sections.

Light

Some seeds require a change in light levels to germinate, whereas others need light levels to remain stable. The grass *Spinifex hirsutus*, or Hairy Spinifex, helps to stabilise coastal sand dune environments in Western Australia and South Australia. In these dry environments moisture and nutrients are found underground, away from the surface. Hairy Spinifex seeds will only germinate if they experience an extended period without light, as this signals to the seed that it is underground and will have access to the nutrients and moisture it requires.

Spinifex hirsutus helps to stabilise coastal dune environments and germinates in response to darkness. Image: M.Fagg, 1977

Sunlight is also an important germination trigger for rainforest species, as the dense forest canopy limits the amount of sunlight that reaches the plants below. Exposure to light can alleviate the physiological dormancy of some rainforest seeds and trigger germination.

Increased light levels are often associated with an opening in the canopy and therefore an opportunity to grow, such as when a canopy tree falls.

- The space will be filled by plants as quickly as they can grow, competing for the best position in the increased sunlight.
- If the canopy and understorey layers of the rainforest remain intact these seeds may never 'see' additional sunlight and may not be triggered to germinate.

- Rainforest plants compete to secure a position with access to sunlight before they even begin to grow. In response to these challenges some rainforest species have evolved the ability to grow on other plants and surfaces rather than in the ground.
- **Epiphytes** (growing on plants) and **lithophytes** (growing on rocks) can live many metres above the ground, providing them with better access to sunlight and certain pollinators than if they were growing at ground level.
- Epiphyte seeds (or spores) take advantage of any surface they can cling to, such as a fork in a tree, a stump where a branch has fallen, a rock or textured bark, and begin to germinate in place.
- Species like the Bird's Nest Fern (*Asplenium nidus*) don't utillise their roots as much as other plants, as they receive water from the rain and nutrients from composting leaf litter that collects amongst their leaves.
- Species like the Sydney Rock Orchid (*Dendrobium speciosum*) produce root mats that bind to each other over rock surfaces and between crevices. Their roots are often covered by a moist layer of ferns and mosses.

This Bird's Nest Fern (*Asplenium nidus*) is an epiphyte.
Image: ©M.Fagg, 2012

Lithophytes like the Sydney Rock Orchid (*Dendrobium speciosum*) can grow on rocks and cliff faces in the rainforest.

Image: ©M.Fagg, 1984

Oxygen

Seeds take in oxygen through their seed coat to undergo **aerobic respiration**. Oxygen is found in pore spaces in the soil so if a seed is buried too deep, or the soil is very compact or wet, there may not be enough pore spaces to meet the seed's oxygen needs. The seeds of flood-irrigated crops like rice can germinate in **anaerobic** conditions as they have a structure called a **coleoptile** that protrudes from the water and acts like a snorkel.

Soil moisture

Mature seeds are often very dry so encountering water can trigger germination. Seeds **imbibe** water through their coat or through a gap that has opened in the coat and use it to convert their endosperm into chemicals that they can use for food. Interestingly, some studies have shown that seeds do not imbibe water as a liquid, but rather as a vapour, and therefore humidity in the seed zone is more important than the environment being wet.

Fire and smoke

Over 400 native Australian plant species, mainly from the fire-prone arid and temperate regions of southern Australia, have seeds that are triggered to germinate after being exposed to smoke or fire. Heat alleviates physical dormancy by breaking the hard seed coat and allowing water uptake. Chemicals from smoke interact with the seed to trigger or speed up germination.

- Once a bushfire has swept through an area it usually removes the groundcover and leaves behind a fertile layer of ash.
- This creates an area that is nutrient-rich, clean and open to sunlight; an ideal environment for seedlings to grow.
- The post-fire environment is so ideal for seedling growth that some species have evolved to only germinate after a fire. These species are termed 'fire ephemerals.' A good example of this is the Pink Flannel Flower (*Actinotus forsythii*).
- *Banksia* seeds are held in the cone of the parent plant. The cone itself is a flower head that has developed from hundreds or thousands of tiny individual flowers grouped together in pairs.
- When pollinated, the flowers grow into a woody seed pod (known as a follicle) with the seed inside. Some *Banksia* species need fire to disperse their seeds. During a fire, the heat can trigger the pods to open and disperse the seeds.
- Some species of *Banksia* also require one or more rainfall events following the fire to trigger germination.

This *Banksia aemula* cone (left) opened and released its seeds after being exposed to fire. The seeds of *Banksia aemula* (right).
Image: ©M.Fagg, 2014 Image: B.Clinton©CANBR, 2017

The Australian native seeds: a digital image library project which is supported through funding from the Australian Government's Australian Biological Resources Study (ABRS) Bush Blitz Program.), Scale is in microns.

Cold

Many seeds are sensitive to temperature and will only germinate when temperatures stay within a certain range or alternate between cool and warm temperatures. Some forms of physiological dormancy are alleviated by temperature, such as alpine species requiring **cold stratification**. Alpine biomes occur at high elevations above the **tree-line**, where trees cannot grow, and experience snow in the winter. Alpine environments have a very limited distribution in Australia, occurring at approximately 1,850 metres elevation in the Australian Alps (from the ACT to NSW and Victoria), and 700–1,000 metres elevation in the central Tasmanian Alps.

The seeds of many alpine plant species lie dormant in soil before germinating, such as Mountain Hovea, *Hovea montana*, and Alpine Marsh-marigold, *Caltha introloba*.

- Cold stratification is a period of cold temperatures followed by warmer temperatures, usually experienced as the season changes from winter to spring, accompanied by moist soil conditions.
- Waiting for this temperature trigger prevents the seeds from germinating early, such as in late autumn, when they may be exposed to damaging frosts.
- Once their dormancy has been alleviated, many alpine seeds undergo **warm-cued germination**, meaning they germinate in response to the warmer temperatures of spring and summer.
- The increasing light levels and changes between night and day temperatures in spring can also trigger germination.
- Alpine species that grow below the tree-line have a weaker response to cold stratification and warm temperatures than species that grow strictly in the alpine zone above the tree-line.

The seed dormancy of Mountain Hovea, *Hovea montana*, is alleviated by cold stratification and germination occurs in response to warmer temperatures.

Image: B.Clinton©CANBR, 2017

The Australian native seeds: a digital image library project which is supported through funding from the Australian Government's Australian Biological Resources Study (ABRS) Bush Blitz Program.), Scale is in microns.

Flowers of the Mountain Hovea (*Hovea montana*).

Image: ©M.Fagg, 2015

Scarification

In some seeds that undergo physical dormancy the seed coat is impermeable to gases so they cannot take in oxygen. These seeds need to be **scarified** before they can take up oxygen and water to trigger germination. **Scarification** can occur when a seed is scratched or eaten by an animal. Often digestive enzymes weaken the seed coat. Some seeds require scarification to trigger germination and are adapted to the digestive tract of particular animal species, such as emus or cassowaries. See previous section: ***Animal dispersal: Cassowaries*** for more information.

Seed pre-treatment

To replicate the conditions required to alleviate dormancy and trigger their germination stored seeds will often need to undergo a form of **pre-treatment.** The method of pre-treatment varies by seed type, but seed scientists, horticulturists and gardeners alike will often use the same method for the same seed species to ensure they will germinate and grow.

Common methods of pre-treatment include:

- exposure to smoke
- exposure to fire
- soaking in boiling water
- soaking in water
- washing in soap or alcohol
- scarring or nicking the seed coat
- exposure to bright light
- exposure to darkness
- exposure to cold or
- exposure to heat.

Australian native pines, *Callitris* species, require a cold stratification pre-treatment of 1–2 weeks in the fridge or 4–12 hours soaking in cool water.

The hard seeds of species of *Acacia*, *Davesia*, *Hardenbergia* and *Kennedia* require soaking and/or scarification pre-treatment to allow germination to occur.

Native saltbushes, such as *Maireana*, *Atriplex* and *Rhagodia* species, require drying before germination can occur. Some species benefit from initial leaching of salt through soaking in water, followed by drying, to facilitate germination.

Pittosporum angustifolium occurs across mainland Australia and is commonly known as Weeping Pittosporum, Native Apricot and Gumby Gumby. The seeds of *P. angustifolium* must be washed in soapy water and then soaked in fresh water to remove the sticky resin that prevents them from germinating. This process needs to be repeated multiple times before the seeds are ready to sow.

The seeds of *Pittosporum angustifolium* have a sticky resin coating that inhibits germination and remains as the seeds dry out. To leach off the resin seeds are pre-treated by repeated washing and soaking.
Image: ©M.Fagg, 1991

Seeds of *Pittosporum angustifolium*.
Image: A.N. Schmidt-Lebuhn©CANBR, 2015

A seed of a *Pittosporum angustifolium*.
Image: B.Clinton©CANBR, 2017

The Australian native seeds: a digital image library project which is supported through funding from the Australian Government's Australian Biological Resources Study (ABRS) Bush Blitz Program.), Scale is in microns.

Seed fill is a measure of the proportion of outwardly undamaged seeds that have all the internal tissues essential for germination (that is, an intact endosperm and embryo). Seed fill has not often been documented separately to seed viability, as seeds must be filled to be viable (although the converse is not true; that is, not all filled seeds are viable).

Martyn, Amelia J., et al. "Seed Fill, Viability and Germination of NSW Species in the Family Rutaceae." 2013.

INQUIRY QUESTIONS (ENGAGE)

Explain the learning intentions for the lesson and introduce the topic to the students.

Ask the students a series of questions such as:

Does a seed grow? What does the word germinate mean?

How does a plant transition from the seed stage of the life cycle to the seedling stage?

What do seeds require to germinate?

Do all seeds have the same requirements for germination?

How do scientists know what seeds of different species need to germinate?

Why is it important that we understand the seed germination requirements of each plant species? How would scientists use this knowledge?

STRATEGIES TO FACILITATE QUESTIONING AND DISCUSSION

- Talk with a partner (turn and talk).
- [1]Think, Pair, Share. (Project Zero Thinking Routine)
- KWL Chart to track what a student knows (K), wants to know (W) and has learned (L) about a topic, can be used before during and after research projects.
- Write in journal and share with others.
- Individual student writing.
- Drawing.

Record students' answers and wonderings on the board or a flipchart.

LESSON SEQUENCE (EXPLORE)

There are three activities in this lesson:

In Activity 1, students will explore how scientists test seed viability and conduct their own viability and quality tests on seeds.

In Activity 2, students will discover some germination requirements of seed of Australian native plants and find some of the differences between species.

In Activity 3, students will investigate how changing a range of factors in a seed's environment can affect its germination and growth.

[1] The Think, Pair Share thinking routine was developed by Project Zero, a research center at the Harvard Graduate School of Education. Project Zero adapted this routine from Frank Lyman: Lyman, F. T. (1981). The Responsive Classroom Discussion: The Inclusion of All Students. In A. Anderson (Ed.), Mainstreaming Digest (pp. 109-113). College Park: University of Maryland Press.

ACTIVITY 1 – TESTING SEED VIABILITY

In this activity, students will learn about seed viability and how and why scientists test for it. They will then carry out their own viability tests.

To do this, you will need:

- Seeds. These can be collected or purchased – many shops sell seeds from Australian native plants.
- Resource: See, Think, Wonder Worksheet for each student
- Containers with water
- Agar
- Petri dishes
- Calculator
- Science journal
- Resource: Seed viability images
- Resource: Tetrazolium (TZ) Test. This is a resource for the educator to use

Instructions:

Part 1: See, Think, Wonder

1. Introduce the lesson intentions and discuss the inquiry questions.
2. Introduce the term viability and what it means in the context of seeds.

   A viable seed contains a living embryo and is capable of germination under suitable conditions.

3. As a class, brainstorm why it is important to test the viability of seeds. Consider points such as:
   - Why do scientists need to know if seeds are viable (able to germinate)?
   - Why is it important to know the percentage of viable seeds?
   - How would scientists test the viability of a seed?

   Make notes as a class to come back to later.

4. Discuss the following points:

   Seed scientists work in seed bank laboratories, studying the quality, storage and germination of each seed collection.

   Seed quality: seed scientists use x-ray analysis to assess if seeds contain an embryo or not. They also conduct viability tests (such as the TZ test) to assess is seed embryos are alive. Knowing the percentage of viable seeds in a sample of seeds allows seed scientists to use maths to determine how viable a collection is overall.

   Seed storage: Seed scientists investigate the best conditions under which to store each collection. For most plant species, dry and cold conditions are best and ensure that the seeds remain alive for hundreds of years. Testing viability before and after the storage of seeds allows scientists to determine whether the storage method is correct.

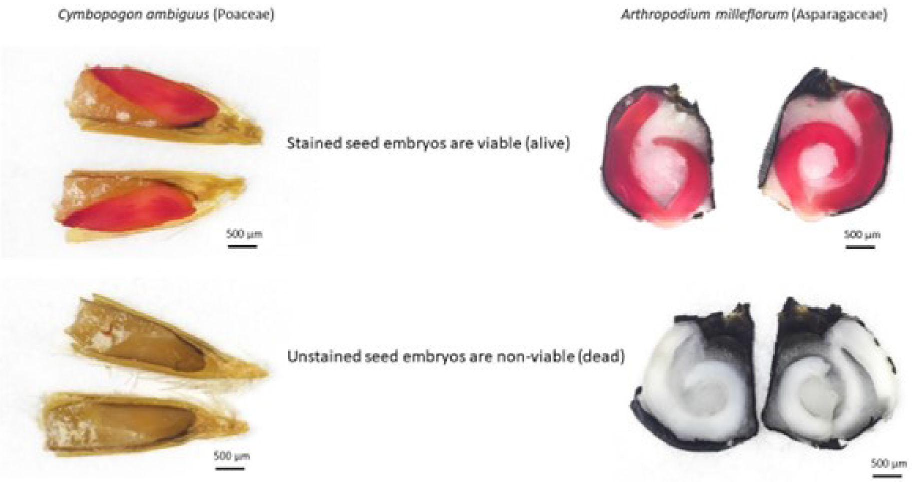
[1] The Think, Pair Share thinking routine was developed by Project Zero, a research center at the Harvard Graduate School of Education. Project Zero adapted this routine from Frank Lyman: Lyman, F. T. (1981). The Responsive Classroom Discussion: The Inclusion of All Students. In A. Anderson (Ed.), Mainstreaming Digest (pp. 109-113). College Park: University of Maryland Press.

[2] The See, Think, Wonder thinking routine was developed by Project Zero, a research center at the Harvard Graduate School of Education.

Seed germination: There is no point storing seeds unless we know how to germinate them. Seed scientists work to uncover the germination requirements of each seed collection. Discovering the germination requirements of thousands of plant species is not a simple task, and sometimes it takes years to 'crack the code' of just one species! Testing the viability of a seed can also help determine whether the seeds' requirements for germination are being met.

If a plant species becomes extinct in the wild, but its seeds are stored in a conservation seed bank, it can be grown again. This is how seed banks can help safeguard species from extinction!

5. Hand out the Resource: See, Think, Wonder Worksheets to each student or have them create this in their science journal. Explain how to participate in the See, Think, Wonder thinking routine if students have yet to do this.
    - In the 'see' section, students explain what they can see in the photos.
    - In the 'think' section, students explain what they think the photos are showing, such as 'I think the seed has the red dye inside it'.
    - In the 'I wonder' section, students record anything that the photos make them wonder, such as 'I wonder why the seeds don't try to keep the dye out?'
6. Show students the images in the Resource: Seed viability images. You may wish to show these on a Smartboard or as printed images for students to look closely at. Have students complete a See, Think, Wonder Worksheet about the Seed viability images.
7. Come together as a class and discuss what students included in their See, Think, Wonder Worksheets. Record any questions that the students have. These can be researched later if they are not answered in the activity.
8. Explain to students how the Tetrazolium (TZ) staining technique works and what it shows. This information can be found in the Resource: Tetrazolium (TZ) Test.



Part 2: Testing seed viability in the classroom

As we learned in Part 1 of this activity, seed scientists use a Tetrazolium (TZ) staining technique to test seed viability. The Tetrazolium (TZ) staining technique is a scientific way of estimating whether a seed is viable (alive). However, if you don't have the tools necessary to do this test, how would you test seed viability?

Home gardeners often use a technique called 'the float test'. This test is not 100% accurate as there are many variables that may affect the results, such as the texture of the seed (fluffy, hairy seeds may float regardless of viability) and seed size (very small seeds may float regardless of viability). However, the float test can give you an idea of which seeds are viable and which seeds are not because non-viable/empty seeds of many plant species float whereas viable/full seeds of many species sink.

Instructions:

1. Explain that you will be conducting an experiment to determine the viability of seeds. Discuss the following:

   The float test gives an indication of the quality of the seeds and, therefore, the potential viability of the seeds.

   Seeds that sink are counted as viable, and seeds that float are counted as not viable.

   Seeds may float because they don't have viable embryos or nutrient stores.

   This experiment has limitations that may affect the results, such as the texture of the seed (fluffy, hairy seeds may float regardless of viability) and seed size (very small seeds may float regardless of viability).

   Not all seeds that float are non-viable. They may just be less healthy than seeds that sink.

   Purchased packets of seeds are likely to have a higher percentage of viable seeds than seeds collected from the field.

2. Using a packet of seeds per group of students or seeds collected previously, have students count how many seeds are in their collection and record this number.
3. Empty the seeds into the water and wait 15 minutes.
4. Count how many seeds float and how many sink. Students should record these values and then convert them to a percentage by dividing the number of seeds that sank by the total number of seeds and multiplying by 100.

   Example: a packet with 50 seeds has 22 that float and 28 that sink

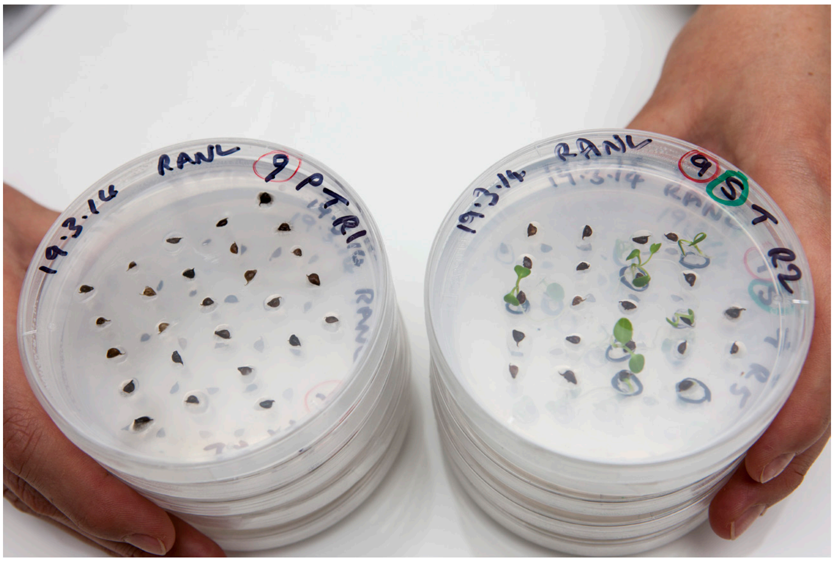
   $28 \div 50 = 0.56$

   $0.56 \times 100 = 56\%$

   We estimate that 56% of the seeds in our collection are viable.

Extension idea

- Germination is the best indication of seed viability. Using the same seeds from the float test, conduct a germination test using agar. Compare results to the estimate from the float test. Are the results the same/similar? See Activity 1 – Germinate a seed, from Plant Life Cycles Lesson 4



Discussion Points:

Why is it important to know if seeds are viable or not?

Is a viable seed alive?

Is a non-viable seed dead?

Which test is more accurate, the TZ test, the float test or the germination test? Why?

The TZ method is not suitable for small seeds. Why do you think this is?

Before you did the experiment, did you think more seeds would float than actually did?

Looking at the non-viable seeds, are they damaged in any way?

How could you change this experiment next time?

ACTIVITY 2 – CODEBREAKER

There are two parts to this activity:

Part 1: Students use riddles and codes to determine the germination requirements of the seeds of two native Australian plants.

Part 2: Students create their own riddle and code using a suggested plant and information on its germination cue. As a further extension activity, students research a native plant of their choice and create a riddle and code to highlight the germination triggers of the plant's seeds.

To do this, you will need:

- Resource: Crack the code worksheet for each student
- Video: 'Life Cycles Part 1' produced for the Life Cycles module (found by searching in the Life Cycles Resources on the Plant Science Learning Hub)

Instructions:

1. Introduce the lesson intentions and discuss the inquiry questions.
2. Discuss the role scientists play in 'cracking the code' of seed germination.

Seed scientists around the world work to 'crack the code' of what each plant species needs to grow. They find the best way to store seeds so they last as long as possible and don't germinate while they are being stored. Discovering the germination conditions needed by thousands of plant species is not a simple task, and sometimes it takes years to 'crack the code' of just one species!

If a plant species becomes extinct in the wild, but its seeds are stored in a conservation seed bank, it can be grown again!

This is how seed banks can safeguard plant species and the Earth's biodiversity!

To germinate seeds (including alleviating dormancy if needed), seed scientists often try to mimic the conditions that seeds experience after they have been dispersed in the wild. This includes the temperatures, moisture conditions and seasonal changes that seeds experience. Sometimes seed scientists also need to apply pre-treatments that mimic disturbance events such as fire, erosion, digestion through an animal and drought.

Once optimal and reliable pre-treatments and germination conditions have been uncovered for a species, this information can be shared among seed scientists, horticulturists and gardeners alike to ensure they can all germinate seeds of that species.

Common seed pre-treatments include:

- *exposure to smoke chemicals*
- *exposure to short durations of 80-120°C in an oven*
- *soaking in boiling water*
- *exposure to running water*
- *chipping or nicking the seed coat with a scalpel (scarification)*
- *exposure to light of different colours*
- *exposure to constant darkness*
- *dry after-ripening: exposure to months of dry, warm conditions*
- *cold stratification: exposure to months of moist, cold conditions (4-5°C)*
- *warm stratification: exposure to months of moist, warm conditions.*
- *A combination of 2 or more of the above!*

Australian native pines (Callitris species) require a cold stratification pre-treatment of 1–2 weeks in the fridge or 4–12 hours soaking in cool water.

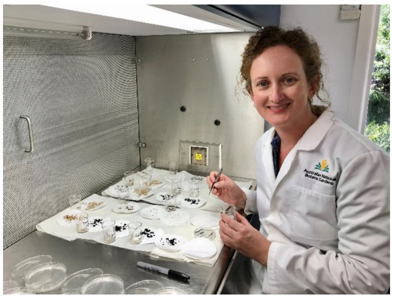
The hard seeds of species of Acacia, Davesia, Hardenbergia and Kennedia require soaking, often in boiling water and/or a scarification pre-treatment, to allow germination to occur.

Native saltbushes, such as Maireana, Atriplex and Rhagodia species, require a dry after-ripening pre-treatment before germination can occur. Some species benefit from the initial leaching of salt through soaking in water, followed by drying, to facilitate germination.

Pittosporum angustifolium occurs across mainland Australia and is commonly known as Weeping Pittosporum, Native Apricot and Gumby Gumby. The seeds of P. angustifolium must be washed in soapy water and then soaked in fresh water to remove the sticky resin that prevents them from germinating. This process must be repeated multiple times before the seeds are ready to sow.

Often, a seed can detect when the right combination of conditions has occurred so it can start to germinate. But many of the germination triggers for Australian plant species aren't known – so seed scientists are codebreakers, trying to determine what these seeds need to germinate!

3. At this point, you may wish to show students the video 'Life Cycles Part 1' produced for the Life Cycles module (found by searching in the Life Cycles Resources on the Plant Science Learning Hub). This video shows Seed Scientist Gemma putting some of these techniques into action.
4. Students will now act as codebreakers to determine each plant's germination requirement. Provide each student with a copy of the Resource: Crack the Code Worksheet. Have students work through it to determine the germination requirements for some Australian plants.
5. Once students have cracked the code, they can complete the associated comprehension questions and create their own riddles and codes.



Discussion Points:

Do plants only have one germination requirement?

How would seed scientists discover if seeds require more than one treatment in a germination experiment?

What are some of the treatments used in germination experiments?

Can you think of any other treatments that may be used in germination experiments?

How would you conduct your own germination experiment?

ACTIVITY 3 – GERMINATION EXPERIMENT

In this activity, students will design an investigation to determine the requirements of a seed for germination. Students will change variables to observe and record the effect on seed germination.

To do this, you will need:

- Small pots or seedling trays
- Soil
- Seeds (using the same species for all treatments will allow for comparable results)
- Other equipment to suit the investigations, e.g. if students are looking at different light levels you will require a lamp, different moisture levels may require a spray bottle etc.
- Students' science journals
- Resource: Investigation planning worksheet
- Resource: Report writing guide

Instructions:

1. Introduce the lesson intentions and discuss the inquiry questions.
2. Review with students the basic requirements of seeds to germinate and grow.

   Some seeds have specific requirements to germinate, such as some banksia seeds requiring exposure to the chemicals in smoke from fires. At this stage, students should think about the main requirements for germination, such as water, the right temperature, light and nutrients.
3. Break students up into small groups and explain that they will be designing their own experiment to study germination. The experiment will focus on observing the effect that different variables have on germination.
4. Discuss with students that when testing one variable, everything else needs to remain the same (controlled).

   For example, if students are looking at how different amounts of water affect germination, they need to ensure that all seeds re provided with the same amount of nutrients, the same temperature and the same light levels. This makes it clear that the amount of water the seeds received is responsible for the observed germination results, rather than a different variable not being investigated.

   Some examples of variables are:

   - Different levels of light, water or nutrients.
   - Different types of nutrients – you could use different soil types or add fertiliser.
   - Different water quality – tap water, boiled water, soapy water, etc.
5. Groups will also need to discuss which outcome they are investigating. For example, is the result investigating whether the seeds germinated or not, or how long it takes them to germinate and start growing?
6. Once each group has decided which result they are observing and which variable they will test, they can design their investigation using the Resource: Investigation planning worksheet.
7. Students can then carry out their experiment, monitor it over the designated time, record observations and, once complete, discuss the results with their peers.

8. Students can summarise their experiment into a report using the Resource: Report writing guide.

Image: ©ANBG,2001

Discussion Points:

Why should only one variable be changed in an experiment?

What would happen to your results if you changed more than one variable?

Why is it important to test different variables?

How do scientists decide which variables to test?

What happens if none of the seeds germinate and grow?

Did you get the outcome you expected? Why or why not?

Would you change your experiment? If so, how?

Are there any failed experiments in science?

Note for teachers

Seed experiments require that something is purposefully changed (the test) and something that is kept the same for comparison (the control). Sometimes the experiment gets interrupted and it has to be set up again in order to get results – that's ok, accidents, mistakes and unforeseen circumstances happen in the seed bank lab too! You may not get the results you were expecting, but either way, they allow you to accept or reject your initial hypothesis. Results are never 'wrong' and always add to the scientific knowledge about the species you are studying.

CONCEPTS EXPLAINED AND VOCABULARY DEFINED (EXPLAIN)

The following resources are provided to assist teachers in facilitating a class session to explain concepts and terms that have been introduced to students through the activities.

- Seeds Teachers' Notes (these can be found in the Seeds resources section of the Plant Science Learning Hub).
- If you have not already shown the video produced by the Gardens, you could use it to engage students in this topic. The video explores the anatomy of a seed, seed features, seed dispersal techniques and the purpose of seed banks.
- This video can be found in the Plant Science Learning Hub Seeds resources section.
- Word wall
- Discussion questions
- Life Cycles Video 1 – Seed to seedling (this can be found in the Life Cycles resources section or by searching on the Plant Science Learning Hub).

APPLYING AND EXTENDING THE LEARNING (ELABORATE)

Applying the learning

Compare viability. Obtain different species of seed and carry out the float test as well as germination tests. Compare the results within one species and between species.

Crack some germination codes. Research seeds from different Australian native plants that have multiple requirements for germination. Compare and communicate your findings.

Germinate seeds for your school. Use what you have learned about germination requirements to germinate seeds and plant them in your school garden.

Write a storybook. Write a storybook for a younger age group about a seed germinating. The story can be from the perspective of the seed or of a person sowing the seed. What does the seed need for germination, and how are these requirements met? What hardships does the seed and seedling face? Does your seed germinate in the end? You could create characters, build a storyline and illustrate your book.

Testing seeds. Go to your local park and find seeds on the ground. Carry out the float test and then try to germinate all the seeds to see how accurate the float test results were. Follow 'General guidance for collecting and exploring our natural environment' found in the Seeds Field Kit for information and legal requirements related to collecting natural material.

Extension ideas for further research

Seed dissection. Open a seed to look inside and see if you can determine its viability and quality. See Plant Life Cycles Lesson 3, Activity 3 – Dissect a seed for instructions.

Extend your germination experiment. Using the same types of seeds you used in Activity 3, repeat your experiment and change a different variable. Try to narrow down the specific light, water and nutrient requirements for the type of seeds you have by repeating the experiment.

Replicate your experiment, at least 3 replicates (A, B and C) of at least 10 seeds.
Scientists replicate experiments because If something out of the ordinary happens to one of the replicates, it will be obvious compared to the others and results can be better explained.

QUESTIONS AND ACTIVITIES FOR REFLECTION (EVALUATE)

Students review and reflect on their learning journey by:

- Revisiting the learning intentions and original inquiry questions:

  Does a seed grow? What does the word germinate mean?

  How does a plant transition from the seed stage of the life cycle to the seedling stage?

  What do seeds require to germinate?

  Do all seeds have the same requirements for germination?

  How do scientists know what seeds of different species need to germinate?

  Why is it important that we understand the seed germination requirements of each plant species? How would scientists use this knowledge?

- Identifying further questions.

  What questions haven't I answered yet?

- Identifying what they learned from others and their own research.

  What new knowledge do I have about seeds that I didn't know before?

RESOURCE – WORD BANK

viability	germination	staining	germination triggers
dormancy	stratification	scarification	seed fill
aerobic	anaerobic		

RESOURCE – TETRAZOLIUM (TZ) TEST

What is it?

The Tetrazolium chloride staining test (or TZ test) is a widely known method of estimating seed viability.

The TZ test aims to determine what percentage of a seed collection is viable (alive) and what percentage is non-viable (dying or dead). This test helps determine what proportion of a seed collection can be expected to germinate under favourable germination conditions. It can also assist in diagnosing seed dormancy.

How does it work?

Seeds are soaked in a colourless solution of TZ, which enters both living and dead cells, but only the living (metabolising) cells turn the liquid red. Thus, living tissue stains red.

The TZ test works because only living cells have respiratory enzymes capable of converting the colourless, soluble compound in the TZ solution into an insoluble red product.

What does it tell us about the seed?

- Red stained areas in a seed tell us which tissues are living and unstained areas tell us which tissues are non-living.
- The size and position of the stained areas and the extent of staining are used to determine if a seed is viable (alive). In particular, we are looking for a uniformly stained and bright red seed embryo.

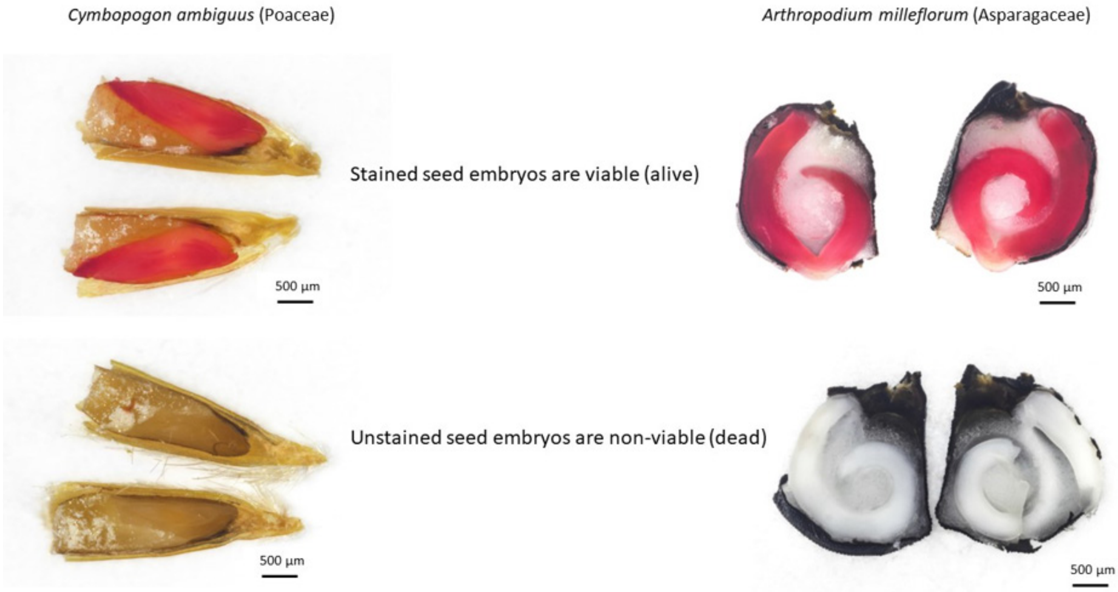
Who uses this test?

The TZ test is routinely employed by seed banks, including the National Seed Bank at the Australian National Botanic Gardens. It is used to distinguish between dead and dormant seed collections when germination tests don't reach a 'pass' (i.e. < 75% germination).

When we fail to achieve >75% germination, we TZ test a small sample of the collection to help answer the question, 'are these seeds dead or dormant?'. When TZ test results are significantly higher than maximum germination, we know we need to do more work to uncover optimal germination requirements and/or dormancy alleviating treatments.

Interpreting TZ staining can be subjective, and there are very limited guidelines for seeds of Australian native species, therefore the TZ test results are considered an estimation of viability, and the TZ test is always used together with other tests, including cut tests, X-ray analysis and germinations tests.

RESOURCE – SEED VIABILITY IMAGES



RESOURCE – CRACK THE CODE WORKSHEET

Can you crack the code?

Part 1

Below are two Australian native plants with seeds that need specific germination cues to germinate.

Read the riddle and use the code to work out what the seeds require.

Can you crack the code?

Grass Triggerplant

Stylidium graminifolium

Riddle

I can be black, white, thin, thick and deadly. I usually stay around for a short time but can last for hours or days.

I can be heavy, but I weigh not…

What do you think I am?

Code

Julius Caesar was a Roman leader born in 100 B.C.E. He was trying to increase the size of the Roman Empire and needed a way of letting his army know the battle plans without the enemy finding out. So, Caesar would write messages to his generals in code. This is known as the Caesar Cipher.

When Caesar wanted to use the letter A, he would instead write the letter that comes three places further on in the alphabet, the letter 'D'.

Instead of writing a 'B', he would write an 'E'. Instead of a 'C', he would write an 'F'.

This plant has used Caesar's alphabet code to disguise what it needs to germinate – can you crack the code of this seed's germination?

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

V P R N H

RESOURCE – CRACK THE CODE WORKSHEET

Comprehension Questions

Why do you think some seeds, including those of the Grass Triggerplant, need this to germinate?

What conditions in Australia might have led to this adaptation?

How could seed scientists provide this germination cue to the seed safely without harming them?

RESOURCE – CRACK THE CODE WORKSHEET

Scarlet Coral Pea

Kennedia prostrata


Riddle

I can be sparkling, but I'm not a star,

I can run, but I don't have legs,

I can fall, but I don't get hurt,

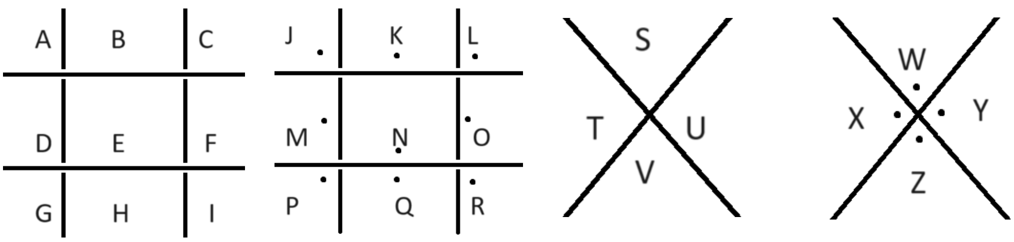
I can help you clean, but I'm not soap...

What do you think I am?

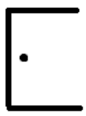
Use the code below to check your answer...

Code

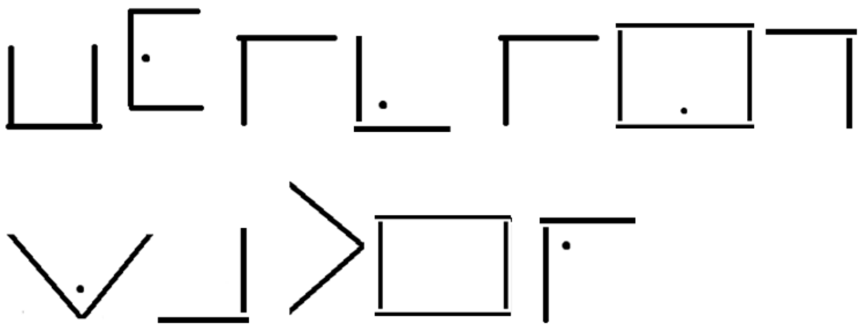
This code is called a pigpen code. You can write secret messages and crack codes using pictures around the letters.



For example:

A=  O=  W=  etc.

Can you crack this code to find out the germination trigger for the seed of a Scarlet Coral Pea?



Comprehension Questions

Why do some seeds, like those of the Scarlet Coral Pea, need this germination trigger? (Hint: think about how thick the seed coat might be).

How could seed scientists make sure the seed gets enough of this resource without providing too much?

RESOURCE – CRACK THE CODE WORKSHEET

Can you crack the code?

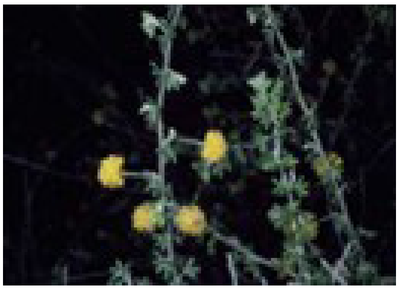
Part 2

Can you make your own riddle and code for a seed?

The Glow Wattle has seeds with a very thick seed coat. They need to be gently scratched so water can get in – then the seed can germinate! We call this scratching process scarification. Try to work out a riddle and a code for this germination cue.

Glow Wattle

Acacia lasiocarpa

Code

Remember, the germination cue you are encoding is scarification.

Answer

Comprehension Questions

Why do you think the Glow Wattle seeds need to be scarified before they can germinate?

How could seed scientists replicate this cue when the seeds are small and easily damaged?
Think: what material could they use to scratch the seeds?

Now research a native plant and the germination cue for its seed. Create your own riddle and code to try on a friend.

Switch with a partner when you're done!

Common Name:

Scientific Name:

Draw your plant

Riddle

Code

Answer

RESOURCE – INVESTIGATION PLANNING WORKSHEET

What do I want to find out?

I am going to investigate...

Hypothesis

A hypothesis is an idea or an assumption that I can test to find out if it is true.

Prediction

This is what I think will happen if my hypothesis is correct.

Independent Variables	Dependent Variables	Controlled Variables
These are the things I will change during the experiment to affect the outcome.	*This is the variable being tested or measured during the experiment.*	*These are the things I am going to keep the same during the experiment.*

To ensure my experiment is a ‘fair test’, I will...

A fair test is a test that controls all but one variable. Only changing one variable allows me to know that no other variable has affected the results.

Risk assessment

These are the hazards I need to manage during my experiment.

Diagram

Draw a diagram (if relevant)

Materials (What equipment do I need?)

The equipment I need is:

Method (How am I going to carry out the experiment?)

The steps I will carry out are:

Results table

Write the headings that are relevant to your investigation.

*				
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Review and reflection	
Looking at my results, I can see that… *I think this is because…*	
What problems or challenges did I have in doing this experiment?	*How could I improve this experiment? (Think about fairness and accuracy).*

RESOURCE – REPORT WRITING GUIDE

Title:

Introduction: (What is this report about?)

Sub-heading 1: (Idea/Question you are answering e.g. plant characteristics)

Paragraph 1: Description and pictures

Sub-heading 2:

Paragraph 2: Description and pictures

Sub-heading 3:

Paragraph 3: Description and pictures

Labelled picture:

Summary/closing Sentence:

Bibliography and references:

RESOURCE: STUDENT REFLECTIONS

Consider displaying sentence starters or questions, such as below, in the classroom. Alternatively they could be turned into laminated thought bubbles that are directly passed to students. Students could choose two or three to complete in their journal then share their responses with the class.

End of lesson reflections	
Today I discovered ... I want to know more about ... Something new I found out was ... I am excited about ... Something I am finding interesting is ... The most challenging thing was ...	I am most proud of ... I feel confident about ... I am enjoying ... because ... I am confused by ... Today I asked ... A question I have is ...

Guiding students to reflect on their own thinking	
I am starting to think differently about ... I got stuck when ... and I got back on track by ... I figured out that ... I solved a problem by ... I first thought ... but then I realised that ...	This idea is useful for ... Some things I didn't understand are ... To help me understand better I will ... Before I didn't know ... Now I realise/know ...

Reflecting on stewardship and taking action	
This information can make a difference by ... It is important to know about this because ... Something I will now do as a result of my learning is ... Something I want to do next is ...	Something I will now help others understand is ... I can make a difference by ... An action I/we can take is ... If we don't ... the consequences could be ... It is important to ... because ...

End of unit reflections – where I was and where I am now	
I used to think ... Now I know ... This causes me to (re)think/ wonder ...	**Revisit** your first journal entry. What do you understand now that you didn't back then? **Review** your work so far. What has been the biggest discovery/learning/challenge? **Reconsider** your initial ideas. Have your ideas changed? If so how?
I didn't know how to ... Now I can ... In the future I will ...	

Source: Source: Great Barrier Reef Marine Park Authority 2015, Animal adaptations: Year 5 Australian science curriculum focus, GBRMPA, Townsville. Used with permission.

Australian National Botanic Gardens