Science by Doing
Engaging students with science

EVOLUTION AND HEREDITY

LESSON PLANS

Australian Academy of Science

Part 1 Evolution – how do species change?

Activity No	Activity Name	Lesson type	Activity Description
1.1	[How did we get such a variety of living things?]	Engage & Evaluate Classroom Short	This **diagnostic assessment** activity is intended to engage student interest in the source of the diversity of life on Earth. Students view a range of images and stimulus questions about the diversity of life. They share their ideas in small groups, and then brainstorm ideas as a class. (Optional)
1.2	[Changing ideas about life]	Explore & Explain Hands-on & Classroom Long	Students explore the contributions of different scientists to our current-day understanding of evolution and ***Notebook*** their findings. In groups, students role-play an issue faced by one of the scientists. The ***Hints*** function can assist students with ideas for the role-play activity.
1.3	[What's the use of variation?]	Explore & Elaborate Digital Medium	In this digital activity students explore variation in the beaks, wings and feet of birds. They use their findings to build a bird that is well-adapted to its environment and explore the effect of different environments on survival of a bird.
1.4	[Tasty selection]	Explore & Explain Digital Medium	Students explore an interactive to see how peppered moth populations change in different environments. They also explore how a beetle population changes over several generations under predation.
1.5	[How do species change?]	Explain & Elaborate Classroom & Digital Medium	Students sequence cards to identify the stages in natural selection, and then relate them to unfamiliar Australian examples. Students use diagrams and videos to learn about other examples of natural selection.
1.6	[Variety is the spice of life]	Explain & Evaluate Hands-on & Digital Long	Students model the natural selection of Darwin's finches and determine the relationship between evolution and biodiversity.

Part 2 Evolution – where's the evidence?

Activity No	Activity Name	Lesson type	Activity Description
2.1	An evolutionary timeline	Engage Classroom Medium	Students demonstrate their existing understanding of the evolution of life on Earth by sequencing cards with key events. They then create and analyse a toilet paper timeline of the evolution of life on Earth.
2.2	Fossil evidence for evolution	Explore & Explain Classroom & Digital Long	Students learn about absolute and relative dating of fossils through video and an interactive activity in the *Digital Resource*. Students analyse and sequence images of transitional fossils that provide evidence for whale evolution.
2.3	Anatomical evidence of evolution	Explore & Explain Hands-on Long	Students identify homologous bones in the forelimb of different vertebrate species and draw conclusions about anatomical evidence for evolution. They explore visual representations of evolutionary relationships (based on anatomy) in the form of cladograms.
2.4	Biogeography as evidence of evolution	Explain & Elaborate Classroom Medium	Students identify biogeographical evidence for evolution from a cartoon of Darwin's voyage to the Galapagos. They manipulate a puzzle of Gondwana to discover how biogeography explains the evolution of the waratah in Australia and the Chilean firebush in South America from a common ancestor 180 million years ago
2.5	Biochemical evidence of evolution	Explore & Explain Classroom Medium	Students discover biochemical evidence to support evolution by analysing differences in the protein cytochrome c across several vertebrate groups. Students compare the biochemical variations with anatomical differences in several vertebrate species.

Activity No	Activity Name	Lesson type	Activity Description
2.6	**Are species still changing?**	Explore, Explain & Elaborate Classroom & Digital Long	Using a **Jigsaw** group strategy, students research four different modern-day examples of evolution. Individual students then present their example to their group, using a provided PowerPoint. A further optional activity explores how cane toads are rapidly evolving in Australia.
2.7	**Isn't evolution just a theory?**	Explain, Elaborate & Evaluate Classroom & Digital Medium	A **formative assessment** task in which student groups use a graphic organiser to plan a balanced scientific argument about the theory of evolution.

Part 3 The DNA information store

Activity No	Activity Name	Lesson type	Activity Description
3.1	**What do you know about DNA and genetics?**	Engage & Evaluate Classroom & Digital Long	A **diagnostic assessment** task in which groups complete graffiti walls to show what they already know about genetics. Students respond to stimulus questions and ***Notebook*** their ideas about scientific issues in the media. (Optional)
3.2	**How was DNA discovered?**	Explore & Explain Digital Long	Students learn of the contributions of different scientists to the discovery of the structure of DNA, through video and an interactive activity. Students creatively present the contributions of five or more scientists.
3.3	**DNA extraction**	Engage & Explore Hands-on Medium	Students extract DNA from dried peas and analyse the steps involved.
3.4	**Big, bigger, biggest**	Explore & Explain Digital Short	Students watch a video about people who have a gene which increases their risk of breast cancer. Students then explore two resources to discover the relationships between the nucleus, DNA, genes and chromosomes. Using a click and drag exercise they demonstrate their understanding.
3.5	**Lolly DNA**	Explore & Explain Digital & Hands-on Medium	Students will discover the structure of DNA using an interactive digital resource. Students then create a lolly model of DNA, using the base-pairing rule to ensure the strands are complementary.
3.6	**Coding for proteins**	Explore & Explain Hands-on Short	Students discover the role of codons in protein synthesis and use their knowledge to find the amino acids coded for by their lolly DNA model (from **Activity 3.5**). Students help solve a crime by analysing the DNA from a crime scene.

Activity No	Activity Name	Lesson type	Activity Description
3.7	Copying DNA for cell division	Explore & Explain Hands-on Medium	Students predict what happens to the amount of DNA in a cell when it divides. They then use their lolly DNA models (from **Activity 3.5**) to simulate what happens during DNA replication. Students consider why DNA replication occurs prior to cell division.
3.8	How do we grow?	Explore & Explain Digital & Classroom Long	Students explore a digital resource and then correctly order clips of the stages of mitosis, to create a video of the process. Students reinforce their learning by ***Notebooking*** and creating a role play of the stages of mitosis.

Part 4 How are genes passed on?

Activity No	Activity Name	Lesson type	Activity Description
4.1	**Making babies**	Engage & Explore Classroom & Digital Medium	Students review the structure and function of the parts of the human reproductive system through an interactive digital resource and play a game of *Making Babies Bingo* to review their learning. Students further explore sexual reproduction in humans and develop explanations for how contraceptives work.
4.2	**Making sex cells with meiosis**	Explore, Explain & Elaborate Classroom & Digital Long	Students watch a short video on meiosis and then sequence the stages of meiosis in an interactive digital activity. Working in groups, students demonstrate their understanding by creating plasticine models of the stages of meiosis. Students compare mitosis to meiosis in a Venn diagram.
4.3	**Why are we all different?**	Explore, Explain & Elaborate Hands-on Medium	Students respond to a series of true or false statements in an ***Anticipation Guide*** before and after learning about sources of variation.
4.4	**Boy or girl?**	Explore, Explain & Elaborate Classroom & Digital Long	Students view a video in which Australian scientists describe sex determination in humans and other vertebrate species. Students ***Notebook*** their learning about different sex determination systems, and predict the effect of climate change on species with temperature dependent sex determination.
4.5	**Dominant and recessive genes**	Explore, Explain & Elaborate Hands-on Medium	Students explore a cartoon about Mendel, before completing a class survey of simple Mendelian traits. Students reinforce their learning about dominant and recessive genes in a digital interactive game. The *Find out more* section introduces multiple alleles, polygenic traits, incomplete dominance and codominance.
4.6	**Heredity – what's the chance?**	Explore, Explain, Elaborate & Evaluate Classroom & Digital Medium	Students learn about Punnett squares and use them to make predictions about inherited characteristics. They test their knowledge of terminology with a crossword puzzle and complete a digital quiz (**formative assessment**). Students then create a fictitious animal using Punnett squares in an online game.

Part 5 When things go wrong

Activity No	Activity Name	Lesson type	Activity Description
5.1	**What's the problem with mutations?**	Engage, Explore & Explain Digital Medium	Students learn about various factors that cause changes to DNA. They explore an interactive DNA molecule to draw conclusions about different types of mutations. In an optional *Find Out More*, students explore real-life examples of both harmful and benign mutations.
5.2	**Family pedigrees**	Explore, Explain, Elaborate & Evaluate Classroom & Digital Long	Students explore pedigree symbols in an interactive pedigree chart and use their understanding to create a pedigree chart for their family. Students complete an interactive quiz as a **formative assessment** task.
5.3	**Sex-linked inheritance**	Explore & Explain Classroom & Digital Long	Students discover how sex-linked conditions are inherited, by modelling what happens to the sex chromosomes of a fictitious couple and through Punnett squares. They explore the use of pedigrees to track sex-linked diseases in a family through the example of haemophilia in Queen Victoria's family.
5.4	**Cleverly used genes?**	Explore, Explain, Elaborate & Evaluate Classroom Long	Student groups explore examples of gene technology (genetic testing, GM crops, and IVF with embryo selection) in a scenario-based card activity. For each scenario, students are presented a range of background information and issues (including social and ethical issues). They debate the issues and make informed decisions about the technology.
5.5	**Sample test**	Evaluate Classroom Medium	A formal test that may be used for **summative assessment** of the concepts covered in the unit.

1.1 How did we get such a variety of living things?

Lesson outcomes

At the end of this activity students will be able to:

- recognise that there is a diversity of life on Earth
- share their ideas to explain how Earth got such a variety of living organisms.

Equipment list

Each GROUP will require:

- Sheet of butcher paper
- Marker

Each STUDENT will require:

- *Student Guide*

Things to consider:

Explain to students that you are interested in finding out what they already know and think about this topic. It is important to remind students that there is no right or wrong viewpoint at this stage. Students may have widely different opinions depending on their background and religious beliefs.

Lesson plan

Step 1: Invite students to look at the images and think about the questions in their student guide.

Step 2: Divide students into small groups. Assign a question to each group to answer.

Step 3: Invite each group to report to the class about the answers they came up with to their question. Seek further ideas from the rest of the class. Put each butcher paper up on display during the unit.

Step 4: Recall students' responses to the questions to plan how to accommodate and challenge prior knowledge during the unit.

1.2 Changing ideas about life

Lesson outcomes

At the end of this activity students will be able to:

- relate the contributions of different scientists towards our current-day understanding of evolution by natural selection
- describe how scientific understanding (including theories) is contestable and is refined over time through a process of review by the scientific community.

What ideas might your students already have?

- Students may believe that Darwin was the first scientist to come up with the idea of evolution.
- Some students may misunderstand the term ‘evolution’ to be an explanation for the origin of life, rather than for how species change over time.

Key vocabulary:

Evolution, inheritance, acquired characteristics, natural selection, Carl Linnaeus, Georges Buffon, Erasmus Darwin, Jean-Baptiste Lamarck, Charles Darwin, Alfred Wallace, HMS Beagle.

Equipment list

Each PAIR or GROUP will require:

- device and internet access

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Teacher content information:

Some of the key contributions from scientists in the timeline towards the development of evolutionary theory include:

c. 1749 Georges Buffon – proposed that species could change (i.e. evolve) and that they have a common ancestor.

c. 1753 Linnaeus – developed a classification system for living things and put humans in the same group as monkeys and apes.

1794 Erasmus Darwin – proposed that species evolve, have a common ancestor and change due to competition for resources.

1801 Lamarck – the first to give a mechanism for how species evolve through ‘inheritance of acquired characteristics’. He believed individual organisms change during their lifetime in response to their environment (e.g. giraffes stretched their necks to reach food higher in trees), and pass on these changes to their offspring. His ideas are not accepted now.

1858 Wallace – proposed similar ideas about evolution by natural selection as Charles Darwin.

1859 Charles Darwin – formally presented his theory of evolution by natural selection with Wallace. Published his famous book *On the origin of species by natural selection*, which contained large amounts of evidence for his theory.

Lesson plan

Step 1: Explain that students will work in pairs or small groups to explore the timeline in chronological order and summarise in one to two sentences the contributions of the six different scientists towards our understanding of evolution.

Step 2: Briefly discuss the second ***Notebook*** question as a class before asking students to ***Notebook*** their response to the question.

Step 3: Explain to students that each group will now prepare a short 3-minute skit on an issue faced by one of the scientists in the timeline. As a class, agree on the time needed to prepare the skit. Refer students to the ***Hints*** function if they need ideas for their role-play.

Step 4: Role plays can be presented either to the class, or to other groups, depending on the time available.

1.3 What's the use of variation?

Lesson outcomes

At the end of this activity students will be able to:

- describe the adaptations of birds to different environments
- explain how the characteristics of living things can affect their survival and reproduction in different environments.

Key vocabulary:

Variation, adaptation.

Equipment list

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebook***

Things to consider

- Teachers should familiarise themselves with this interactive resource before using it.
- Although students should work independently, they will feel more confident in their responses if allowed to discuss their answers with a **Learning Partner**.

Lesson plan

Step 1: Allow students 5-10 minutes to explore the three resources covering variation in the beaks, wings and feet of birds.

Step 2: Invite students to start the ***Notebook*** activity.

Step 3: Conclude by inviting students to share their new understandings with the class.

Suggested question/s:

- What does success of a species mean?
- Other than availability of food, what else can affect survival of a bird population?
- Why might variation within a bird population be a good thing, if the environment changes?

1.4 Tasty selection

Lesson outcomes

At the end of this activity students will be able to:

- describe how there is existing variation in peppered moth populations and explain how peppered moth populations change in response to their environment through natural selection.

What ideas might your students already have?

- students often believe that individual organisms, rather than populations, adapt to their environment.

Key vocabulary:

Adaptation, natural selection, reproduction.

Equipment list

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebook***

Things to consider

- The interactive at http://peppermoths.weebly.com/ requires Flash Player. Ensure your browser can activate Flash Player. Note – Adobe Flash Player is not supported on iOS devices including the iPad and iPhone. Users can download Photon Flash Player from the App Store and use this browser to play the interactive.

Teacher content information:

The peppered moth and beetle examples of natural selection involve the following concepts:

- There is existing variation (in colour) between individuals in a population.
- Some variations (colours) help individuals to survive better in their environment.
- Those variants reproduce more than others.
- The resulting offspring inherit successful features and produce more offspring themselves.
- Over many generations, the population will develop more individuals with features suited to their environment (adaptations).

Lesson plan

Step 1: As a class, go through each of the physical and behavioural adaptations in the *Student Guide* for the echidna, wasp, sawfly and kangaroo.

Suggested question/s:

- Do you think the kangaroo example is a behavioural or a physical adaptation, or both?
- Can you think of other examples of mimicry or behavioural adaptations?
- How do you think populations become adapted to their environment?

Step 2: Explain to students that they will be finding out how populations adapt to their environment through a simulation of a real example of change in a species. Invite students to explore the interactive and complete the ***Notebook*** questions.

Step 3: Conclude by inviting students to share their new understandings with the class.

1.5 How do species change?

Lesson outcomes

At the end of this activity students will be able to:

- explain how inherited characteristics can affect the survival and reproductive rates of organisms
- describe the process of natural selection including overproduction, variation, selection, reproduction and adaptation.

Key vocabulary:

Inherited characteristics, overproduction, variation, selection, reproduction, adaptation

Equipment list

Each PAIR will require:

- **Activity Sheet 1.5 Natural selection cards** (download from Teacher Guide)
- scissors

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- internet access
- headphones (optional)

Things to consider:

- Consider whether students should watch the videos as a class or individually (headphones may be needed).

Teacher content information:

'Natural selection' versus 'Survival of the fittest'.

Herbert Spencer (27 April 1820 – 8 December 1903) was an English philosopher and a contemporary of Charles Darwin. He read Darwin's *On the Origin of Species* and was the first to coin the term 'survival of the fittest' as an alternative to Darwin's 'natural selection'. By 'fittest' he meant the individual that will leave the most copies of itself in successive generations.

Alfred Wallace suggested to Darwin that he should adopt the term as an alternative to 'natural selection'. Darwin agreed and incorporated it in his fifth edition of *On the Origin of Species*.

While the phrase 'survival of the fittest' is often used to refer to 'natural selection', it is avoided by modern biologists, because the phrase can be misleading. The word 'fit' is frequently confused with a state of physical fitness. Many students misinterpret the term 'survival of the fittest' as meaning survival of the 'strongest', rather than the better survival of those most suited to their environment. For these reasons we have stuck with the term 'natural selection' and have not introduced the term 'survival of the fittest'.

Lesson plan

Step 1: Provide each student pair with **Activity Sheet 1.5 Natural selection cards** and scissors. Ask them to cut out the six sets of cards.

Step 2: Remind students of the peppered moth and beetle examples of natural selection from **Activity 1.4**. Ask students to begin with the five *Natural* selection event cards (cards with a triangle) and put them into the correct sequence.

Step 3: Check that students have sequenced the *Natural selection event* cards as:

- Overproduction
- Variation
- Selection
- Reproduction
- Adaptation

Step 4: Ask students to sequence the remaining sets of cards using the *Natural selection event* cards as a template.

Step 5: Invite students to click on the digital link and explore further examples of how species change through natural selection. You might consider having a class viewing of the hummingbird and anole lizard videos.

Step 6: Encourage students to complete the ***Notebook*** tasks.

Step 7: Discuss answers to the ***Notebook*** questions. Clarify any misunderstandings.

1.6 Variety is the spice of life

Lesson outcomes

At the end of this activity students will be able to:

- describe the role isolation can play in the evolution of new species
- describe biodiversity as a function of evolution
- list several reasons for preserving biodiversity.

What ideas might your students already have?

- Students may believe that individual organisms adapt to their environment during their lifetime.

Key vocabulary:

Ancestor, biodiversity, evolution, adaptation.

Equipment list

Each GROUP of four students will require:

- tray of mainland food (mixed rice, pumpkin seeds, dried beans and Polystyrene balls)
- tray of island food (either rice, pumpkin seeds, dried beans or Polystyrene balls)
- 4 different types of 'beak' – forceps, tooth pick, peg, two chopsticks
- 1 stopwatch
- 4 disposable cups

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider:

Students should only use their 'beaks' to collect the 'food'. They should not touch the food with their hands or modify the 'beak' in any way. Only tooth pick beaks can be used to stab food.

Teacher content information:

The Galapagos finches vary in the size and shape of their beaks and some species are specific to some islands. However, on some islands there are up to 13 species of finches coexisting. Evolutionary biologists surmise that both of the following occurred:-

- allopatric speciation - speciation that occurs when populations of the same species become isolated geographically and evolve separately
- adaptive radiation - varying beak size and shape enabled specialisation of food sources leading to several species of finches inhabiting the same environments without competition or lack of resources.

Different beaks are suited to different food sources. Birds with beaks that are better-suited to the food available on an island, will survive and reproduce better than birds with less-suited beaks. Over many generations, better-suited birds will become more common in the population – the population will have adapted to the conditions on the island. As bird populations adapt, they will become increasingly different from the original population on the mainland and populations on other islands. Evolution will have caused an increase in the variety of birds, i.e. an increase in bird biodiversity.

Lesson plan

Step 1: Explain to students that they will be modelling the feeding success of birds with different shaped beaks. Their birds will start off on the mainland where there is a range of food types. They will then migrate to several offshore islands where each island has a different type of food available for the birds to feed on.

Step 2: Invite students to form groups of four and each student is to adopt a different 'beak' (forceps, tooth pick, peg or two chopsticks). Invite students to complete Steps 1-6 in their *Student Guide*.

Step 3: Draw or project Table 2 onto the whiteboard for groups to fill in their results.

Step 4: Repeat steps 1 – 6 for Island feeding. Provide each group with a tray of island food (either rice, pumpkin seeds, dried beans or Polystyrene balls).

Step 5: Draw or project Table 4 onto the whiteboard for groups to fill in their results.

Step 6: Students may now complete the discussion questions. Compare and discuss.

Step 7: Invite students to begin the digital activity and complete the ***Notebook*** task.

2.1 An evolutionary timeline

Lesson outcomes

At the end of this activity students will be able to:

- sequence the key events in the history of life of Earth
- appreciate the relative timescales of key events in Earth's history.

What ideas might your students already have?

Students may believe that complex life, including human life, evolved much earlier in Earth's history than it actually did.

Equipment list

The CLASS will require:

- **Activity sheet 2.1 Key event cards** (download from Teacher Guide)
- 1 or 2 rolls of toilet paper (at least 230 sheets)
- a corridor or open area
- cameras (e.g. mobile phone)

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- Camera (e.g. mobile phone)

Things to consider:

- Ensure students do not click on the digital link until after they have attempted to sequence the cards.

Lesson plan

Key events in the evolution of life.

Step 1: Ask 12 students to stand in a line in front of the class, each holding a key event card.

Step 2: Ask the remaining students to suggest where each student should stand to show the correct sequence of events in the history of life on Earth.

Step 3: When the class has agreed on the sequence of cards, ask students to click on the digital link in the *Student Guide* and check against the *Table of key events in the evolution of life*.

Toilet paper timeline

Step 4: Move the class to an open area and unroll a line of toilet paper 230 sheets long.

Step 5: Ask the students with the key event cards to look on the *Table of key events in the evolution of life* and to stand at their respective positions on the toilet paper timeline holding their key event card.

Step 6: Ask the remaining students to take the two photos of the timeline.

Step 7: Ask students to answer the ***Notebook*** questions. Conclude with a class discussion of the ***Notebook*** questions and ask students how their ideas changed after making their timeline.

Suggested question/s:

- Did any of the timings of key events surprise you?
- How have your ideas about the appearance of the major groups on Earth changed?
- If Earth's history was represented by a 24 hour clock, what time do you think humans would have appeared?

2.2 Fossil evidence for evolution

Lesson outcomes

At the end of this activity students will be able to:

- provide examples of fossils showing evidence of past life and of evolutionary change over time.

Key vocabulary:

Transitional fossil, absolute dating, relative dating.

Equipment list

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- **Activity sheet 2.2 Fossil evidence for whale evolution** *(*download from Teacher Guide)
- scissors
- glue

Things to consider:

The ***Find out more*** section includes a map of Australia showing the locations of important fossil sites that contain valuable evidence for the evolution of life. The Shark Bay, WA and Nilpena, SA sites both contain 360° Interactive Panorama that play well on desktop computers, laptops, iPads, tablets and smart phones. The Nilpena, SA site also allows for a more immersive 3D experience if you have access to Google Cardboard Virtual Reality Glasses or Virtual Reality headsets.

Teacher content information:

Fossils provide scientists with evidence for evolution by showing:

- what past life was like
- the gradual change of organisms over time (through transitional fossils)
- a general increase in complexity of living things over time

The order of the cards from oldest fossil to most recent fossil is 2, 5, 4, 3, 1.

Lesson plan

Step 1: Project the *Student Guide* (**Activity 3.2**) and discuss the images of rock layers and Archaeopteryx with the class.

Suggested question/s:

- What do you think these fossils tell us about past life on Earth?

Darwin used fossils to support his ideas about evolution. How do you think fossils could provide support for Darwin's theory of evolution?

Step 2: Invite students to open the *Digital Resource* to learn about fossil evidence for evolution.

Step 3: Briefly discuss responses to the ***Notebook*** questions before referring students to the *Student Guide*. Inform students that they are now going to become ‘palaeontologists’, and piece together the fossil evidence for how whales have evolved.

Step 4: Distribute **Activity sheet 2.2 Fossil evidence for whale evolution** and tell students that they will now piece together the fossil evidence for how whales have evolved. After cutting out the cards, students can work in small groups to determine the correct order of cards to show the evolution of the whale.

Step 5: After students have sequenced their fossil cards, notify them of the correct order of the cards – oldest 2, 5, 4, 3, 1 most recent. Allow time for students to complete the discussion questions in their ***Notebooks***.

Step 6: Conclude with a class discussion summarising the ways that fossils provide evidence for evolution.

Step 7: If time permits, students can explore the ***Find out More*** section of the *Digital Resource* to learn about important fossil sites in Australia.

2.3 Anatomical evidence for evolution

Lesson outcomes

At the end of this activity students will be able to:

- describe examples of anatomical evidence for evolution (for both homologous and vestigial structures)
- interpret and analyse evolutionary relationships using a cladogram based on comparisons of anatomy.

Key vocabulary:

Homologous structure, analogous structure, vestigial structure, anatomy, cladogram.

Equipment list

Each GROUP will require:

- skeleton of a chicken wing
- skeleton (or picture) showing bones in a human arm
- five coloured pencils

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- **Activity sheet 2.3 Anatomical evidence of evolution** (download from Teacher Guide)

Comparing the human arm with a chicken wing

What to do:

Step 1 Compare the bones of the chicken wing to those in the human arm and discuss similarities and differences with your group.

Step 2 Record the similarities and differences in your ***Notebook***.

Comparing forelimbs of animals

What to do:

Step 1 Colour each of the bones a different colour in the key in **Activity sheet 2.3 Anatomical evidence for evolution**. Use the same colours to colour each bone in the forelimbs of each animal.

Step 2 Draw a diagram of the chicken wing.

Step 3 As you complete the information in columns 2 and 3 of the table, think about each animal's habitat and how it moves in its environment.

Things to consider

This activity could be conducted over two lessons. Complete **Activity sheet 2.3 Anatomical evidence for evolution** and the discussion of homologous structures in the first lesson, then cover vestigial structures and cladograms in the second lesson.

To prepare the chicken wing skeletons:

- Boil the fresh wings for 1-2 hours, or until the meat falls off easily.
- Cool, remove meat and wash bones in a bowl of soapy warm water.

- Rinse bones in tap water.
- To whiten, soak bones in a bucket of 5% bleach solution overnight, then rinse in tap water.
- Dry bones completely.

Alternatively, each group can be given a fresh chicken wing and asked to remove the skin and muscle from it. Groups will require dissecting equipment and trays to do this. Ensure you provide safety instructions. Hands, benches and equipment will need to be thoroughly washed at the end of the dissection to avoid salmonella contamination.

Teacher content information:

Vertebrates such as humans, other mammals, and birds share a similar forelimb called the pentadactyl limb. Across these groups, the forelimb has the same bones (the humerus, radius, ulna, wrist bones and fingers) suggesting that these groups share a common ancestor that had a pentadactyl limb. Though similar, the bones have been modified in different species depending on their environment e.g. the mole's forelimb has changed (evolved) to become adapted for digging underground.

Lesson plan

Comparing the human arm with a chicken wing

Step 1: Introduce the lesson by telling students that they will be discovering some different ways that the structure (anatomy) of organisms, provides us with evidence that evolution occurs.

Step 2: Refer students to the picture of a fruit bat wing in the *Student Guide*.

Suggested question/s:

- Like humans, bats are mammals. According to evolution, mammals share a common ancestor. How do we know that bats and humans have evolved from a common ancestor?

Step 3: Organise students into groups of 3-4. Invite students to complete Steps 1 and 2.

Suggested question/s:

- What was similar/different about the forelimb of humans and birds?
- Can you explain these similarities/differences?

Comparing forelimbs of animals

Step 4: Distribute **Activity sheet 2.3 Anatomical evidence for evolution** and the sets of coloured pencils.

Step 5: Ask students to complete the remainder of the activity. Remind them to think about the environment of each animal, as they fill in the second and third columns of the table.

Step 6: Project the images of vertebrates in **Activity sheet 2.3 Anatomical evidence for evolution** and as a class, briefly summarise the observed similarities and differences in bone structure. Use a Think-Pair-Share strategy to address the discussion question:

- How could these anatomical (structural) similarities and differences support the theory of evolution?

Step 7: Project and discuss the image of different digestive tracts in mammals from the *Student Guide*. Explain to students that similar structures like this, that provide evidence of common ancestry, are called 'homologous structures'. Ask students to find out the difference between 'homologous' and 'analogous structures'.

Step 8: Project and discuss the images of vestigial structures in the *Student Guide*.

Suggested question/s:

- How do vestigial structures provide evidence for evolution?
- Can you think of another vestigial structure in humans?

Step 9: Invite students to review the page on cladograms in the *Student Guide* and ***Notebook*** their answers to the four questions. Discuss student answers to 'Does this cladogram show humans evolved from monkeys?' Stress to students that neither present-day humans nor present-day monkeys existed in the past; only their ancestors.

2.4 Biogeography as evidence for evolution

Lesson outcomes

At the end of this activity students will be able to:

- explain how biogeography provides evidence for evolution

What ideas might your students already have?

Students should have a knowledge of plate tectonics and the supercontinents: Pangaea/Gondwana.

Key vocabulary:

Biogeography, Pangaea, Gondwana, waratah, Chilean firebush, Embothriineae

Equipment list

Each STUDENT will require:

- *Science by Doing **Notebook**.*
- **Activity Sheet 2.4 Biogeography** (download from Teacher Guide)
- scissors
- glue

Teacher content information:

Scientists use biogeography as evidence for evolution, by looking at changes in populations in response to their geographical distribution. For example:

- Birds that have migrated to offshore islands show evolutionary change in response to the island environment. However, they also show similarities to ancestral populations on the mainland.

When supercontinents, like Pangaea and Gondwana, were broken up by plate tectonics, the environment changed as new continents moved relative to the equator. Species (like some members of the *Embothriinae*) that shared a common ancestor on the supercontinent, have evolved/changed in response to this changing environment.

Lesson plan

Step 1: Tell students that they are going to be learning how Darwin used the geographic distribution of species (their biogeography) to support his ideas about evolution. Ask students to read the cartoon of Darwin’s voyage to the Galapagos Islands.

Step 2: Write the following question on the board and invite students to discuss their answer to the question in pairs. Ask students to ***Notebook*** their response to the question:

- How did the <u>location</u> of the different finches support Darwin’s developing ideas about evolution?

(Hint: geographical location affects the environment**)**

Step 3: Distribute **Activity Sheet 2.4 Biogeography** and ask students to complete the activity, writing their responses to the questions and pasting or photographing their final map in their ***Notebooks***.

Students can open the **HINTS** button from the *Student Guide* and see the correct arrangement of continents to form Gondwana.

Step 4: You might like to show students the following animation which shows the movement of tectonic plates from 180 million years ago to the present.

(***Click** on picture to follow link. Allow the program time to load*).

2.5 Biochemical evidence of evolution

Lesson outcomes

At the end of this activity students will be able to:

- explain how biochemistry, including protein and DNA structure, provides evidence for evolution
- recognise that proteins are made up of sequences of amino acids
- interpret cladograms, based on biochemical comparisons, for evolutionary relationships.

What ideas might your students already have?

Students will have heard of the terms ‘gene’, ‘DNA’ and ‘chromosome’, but may have limited understanding of what they are. These terms will be covered in further detail in Part 4. Students should have an understanding of cladograms from **Activity 2.3 Anatomical evidence for evolution.**

Key vocabulary:

Gregor Mendel, biochemistry, cladogram, DNA, chromosome, gene, protein, amino acid, cytochrome c.

Equipment list

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- *Student Guide*

Things to consider

- Students should have an understanding of cladograms before completing this activity. If not already covered, you may wish to go through the *Student Guide* in **Activity 2.3**.

Teacher content information:

Comparisons of the biochemistry of different organisms can be used as evidence for evolution.

- The structure of common molecules, such as DNA and specific proteins, is similar in closely related species. Variations in structure increase, the more distantly related species are.
- This supports the idea that species have evolved from a common ancestor (with similar biochemistry), and that the longer ago species separated from a common ancestor, the more time they have had for changes to accumulate in these molecules (due to mutations and natural selection).
- cladograms can be used to show evolutionary relationships based on biochemical comparisons.

Lesson plan

Step 1: Ask students to read the information in the sections “Issues with the inheritance’ and “Evidence from inside cells” in the *Student Guide*. Reinforce the key points either through class discussion or through a ***Facts and falsehoods*** activity (***Facts and falsehoods*** - Students individually create a list of statements based on what they have read. Some of the statements are true and others are false. Students swap their statements with a partner and try to work out which are true and which are false.)

Step 2: Tell students that they are going to discover how another type of molecule, a protein, can provide evidence for evolution. Show students the cladogram of the apes and explain that it was made from comparing biochemicals (e.g. DNA and proteins).

Step 3: Take students through the section ‘Comparing proteins’. This will be their first direct encounter with proteins and it is important that students understand that proteins are molecules that perform tasks in the body due to their special shape. Their shape comes from the order of amino acids and the way the linear chain folds up into a three-dimensional shape.

Step 4: Invite students to tackle the discussion questions in their ***Notebooks***. Project the discussion questions and discuss student responses to each one.

Follow up:

You may wish to project some other cladograms to provide students with practice interpreting them. For example, this is a good opportunity to address the common misconception that ‘humans evolved from monkeys’ by projecting the primate family tree at http://humanorigins.si.edu/evidence/genetics

Suggested question/s:

- When was the last common ancestor of chimpanzees and humans?
- When was the last common ancestor of lemurs and tarsiers?

Looking at this family tree, what is wrong with the statement “Humans evolved from monkeys”?

2.6 Are species still changing?

Lesson outcomes

At the end of this activity students will be able to:

- describe modern-day examples of evolution by natural selection, including:
  - artificial selection
  - development of resistance of bacteria to antibiotics, and
  - development of resistance of insects to pesticides
- recognise that, in some cases, evolution can occur rapidly.

What ideas might your students already have?

- Students may think that evolution cannot be observed directly
- People often believe that evolution is always a slow process, taking many thousands of years.

Key vocabulary:

Artificial selection, selective breeding, resistance.

Equipment list

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- Internet access

Things to consider

- Think about the structure of your groups beforehand. Spreading weaker students between groups is probably a good idea.
- Familiarise yourself with the information in the digital resources.
- Consider the best set-up for computer access, you may decide to use 1-2 computers per topic (to encourage collaboration) or 1 per student. Keep in mind that students will need to be able to present the PowerPoint to their group at the end of the activity.
- The PowerPoint cannot be modified.

Lesson plan

Step 1: Introduce the task, projecting and referring to the questions in the *Student Guide*.

Step 2: Click on the digital link. Explain the idea of a ***Jigsaw*** activity and divide students into groups of four. Give groups time to decide who will research each example.

Step 3: Ask students to move into ‘expert groups’ to conduct their research (students join others, from different groups, that are researching the same topic). Explain that they will need to make notes in their ***Notebooks*** so that they can explain the provided PowerPoint slides on their topic to their original group.

Step 4: Circulate to ensure all students are making progress and to estimate the best time to reform groups (20 minutes is probably enough).

Step 5: Students report back to their original group. Each student presents their information to the group using the provided PowerPoint. You may wish to ask the rest of the group to ***Notebook*** key points from each presentation.

Step 6: Return to the *Student Guide* to explore the work of Prof Rick Shine and his team at the University of Sydney on the current, rapid evolution of faster-moving cane toads in Australia. This optional activity encompasses the interpretation of a distribution map and graphs and shows students that there are recent developments in the subject of evolution.

2.7 Isn't evolution just a theory?

Lesson outcomes

At the end of this activity students will be able to:

- consider the role of different sources of evidence for evolution by natural selection
- construct a scientific argument showing how evidence supports their claim
- use scientific evidence to support a conclusion.

What ideas might your students already have?

- Students will have an understanding of different sources of evidence for evolution from **Activities 2.2-2.6**.
- Many people misunderstand the term theory to mean a hunch, or a guess. The video in this activity will help to address this misconception.

Key vocabulary:

Theory, misconception, argument, counter argument.

Equipment list

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebooks***
- **Activity sheet 2.7 Persuasion map and rubric** (download from Teacher Guide)

Things to consider

- This activity is suited to small groups of 2-3.
- Consider how best to structure groups, pairing stronger and weaker students together may be beneficial.

Teacher content information

Reasons for evolution being more than 'just a theory' could include any of the following:

- the word 'theory' in science has a different meaning from 'theory' in everyday language
- there is abundant scientific evidence to support the theory of evolution
    - fossil evidence
    - anatomical evidence
    - biogeography
    - biochemical evidence
    - current-day examples
- theories can be refined over time, this doesn't make them wrong

Lesson plan

Step 1: Project the *Student Guide* and briefly discuss the mock headlines with the class.

Suggested question/s:

- What do you think about these headlines?
- How would you reply to the student's statement that "Evolution is just a theory"?

Step 2: Invite students to explore the digital activities. You might like to project the video and watch as a class.

Step 3: Organise the students into pairs and out **Activity sheet 2.7 Persuasion map and rubric**. Tell students that in pairs they are going to argue a scientific response to the student's statement 'Evolution is just a theory'. To make sure they provide a well-reasoned argument, they will be presenting it using the persuasion map and rubric provided. This is their chance to show what they have learnt so far.

Step 4: Go through the instructions in the *Student Guide* and the components of a good argument. Draw attention to the first column in the rubric describing a good argument.

Step 5: Circulate to ensure all students are making progress and to guide groups where necessary. Ensure groups have time towards the end of the lesson to peer review another persuasion map using the rubric.

Step 6: Collect the persuasion maps in order to provide your feedback to student groups.

3.1 What do you know about DNA and genetics?

Lesson outcomes

At the end of this activity students will be able to:

- share their knowledge of DNA, genetics and gene technology
- share their opinions about some current and contentious scientific issues.

Key vocabulary:

DNA, deoxyribonucleic acid, gene, genetics, paternity testing, mutation, double helix, chromosomes, Down syndrome, gene therapy, designer babies, GMO (genetically modified organism), GM food (genetically modified food), gene testing, in vitro fertilisation (IVF).

Equipment list

Graffiti walls

The CLASS will require:

- six sheets of poster or butcher paper
- three *graffiti walls*: have two sheets of poster or butcher paper in each area labelled with one of the three topics (DNA, Genetics, Gene technology)

Each GROUP will require:

- differently coloured marker for each student

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- Internet access

Things to consider

This diagnostic assessment activity is designed to engage students and for the teacher to assess students' knowledge on the subject. If time is short you may consider running only one of the two activities.

Graffiti walls

- The graffiti walls will be displayed on the classroom walls throughout the unit, so encourage students to use large, clear writing.
- This activity works best with six groups with four-to-five students per group.
- Remind students there are no right or wrong answers at this stage. Explain you wish to understand what they already know about this topic.

Notebook: **What's your opinion?**

- Familiarise yourself with the digital resource to decide the best way to support your students' learning and manage internet access. The learning experience has been designed to put technology into the hands of the students, with the teacher taking a facilitating role.
- It is important to remind students that there is no right or wrong viewpoint for each issue. Students may have widely different opinions depending on their background, media exposure and religious beliefs. Explain that by the end of the unit, they will be better able to argue and justify their point-of-view.

Teacher content information

The NSW Government's Centre for Genetics Education (CGE) produces genetics fact sheets to help individuals, families and health professionals better understand genetic health information, testing techniques and the impact genetics has on health and the community (http://www.genetics.edu.au/publications-and-resources/facts-sheets).

In particular, you might like background material about:-

Genetic testing (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-15-genetic-and-genomic-testing)

Pre-Implantation Genetic Diagnosis (PGD) (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-29-preimplantation-genetic-diagnosis-pgd)

Lesson plan

Graffiti walls

Step 1: Explain that students will be learning about DNA and genetics. What do they know already? You may pose the following questions from the *Student Guide*:

- How do we inherit characteristics from our parents?
- What do people mean when they say 'it's in his/her genes'?
- What is gene technology?

Step 2: Outline the activity in the *Student Guide* and invite students to form six groups of four to five students.

Step 3: Ask groups to complete the ***Notebooking*** step, deciding as a class how much time they will need (usually about 10-to-15 minutes).

Suggested question/s:

1. What do the images show?
2. How do they relate to the topic?
3. What else do you know about each of the three topics?

Step 4: Distribute markers to groups. Assign groups to *graffiti walls* and ask students to write clearly or draw what they know about the topic on that wall. They can write in any direction or anywhere on the paper, as shown in the *Student Guide*. Each student must contribute.

Step 5: Move groups to a different graffiti wall after an agreed period (5-to-10 minutes).

Step 6: Repeat **Step 5**.

Step 7: When groups have completed all three topics, select groups to present the information on their last *graffiti wall* to the class**.**

Suggested question/s:

- Can you tell me about some of the information on your wall?
- Can you tell me about what you wrote?
- Is there anything on your wall you would like to know more about?

What's your opinion?

Step 1: Explain that students will be exploring some contentious scientific issues that are often in the media. During the unit they will explore how characteristics are inherited and they will learn how to argue their point-of-view on a scientific issue.

Step 2: Introduce the digital activity. Invite students to complete the ***Notebook*** task individually, as they work through each of the three scientific issues. They can use the **Hints** to get some ideas for positive and negative aspects of each issue.

Step 3: Explain to students that they will now show where they stand on each issue by taking up a position across the classroom. For each issue, invite students to stand at one end of the room if they agree, the other end of the room if they disagree, or somewhere across the continuum (middle of the room) if they have mixed feelings.

Step 4: For each issue, invite a few students, across the continuum, to explain their position to the class. Allow others to respond to their ideas.

Step 5: After the voting activity, encourage the class to ***Notebook*** any new ideas that they did not think of (you may wish to list ideas on a whiteboard during the voting activity).

Step 6: Explain to students that they will be revisiting some of these issues later in the unit, after they have learnt more about the science behind each issue. Collect and read the students' ***Notebook*** entries. Use their responses to plan how to accommodate and challenge prior knowledge during the unit.

Suggested question/s:

- Explain why you voted in that position?
- Who disagrees/agrees with that viewpoint? Why?

Follow up:

Use the information in the graffiti walls to plan how to accommodate and challenge prior knowledge during the unit.

3.2 How was DNA discovered?

Lesson outcomes

At the end of this activity students will be able to:

- describe the contributions of different scientists towards the development of the Watson and Crick double-helix model of DNA
- appreciate that scientific knowledge and models are developed and refined over time, through the contributions of a number of scientists.

Key vocabulary:

Double-helix model, bases, DNA, deoxyribonucleic acid, hereditary, X-ray diffraction, Oswald Avery, Erwin Chargaff, Rosalind Franklin, Maurice Wilkins, James Watson, Francis Crick.

Equipment list

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebook***

Things to consider

- You may need two lessons to complete this task, or to ask students to complete their creative presentations as homework.
- Allow time for students to present their work to the class.

Teacher content information:

Key contributions from scientists

Scientist	**Contribution towards discovery of structure of DNA**
Oswald Avery (1944)	Oswald Avery's group showed DNA carried hereditary information (although the structure of DNA was not yet understood by scientists).
Erwin Chargaff (1949)	Noticed that within every DNA molecule, the percentage of A bases was always very similar to the percentage of T bases, and that the percentage of C bases was always very similar to the number of G bases.
Maurice Wilkins	Used X-ray diffraction to look at the structure of DNA.
Rosalind Franklin (1952)	Worked with Wilkins using X-ray diffraction to look at the structure of DNA. Her image showed Watson and Crick that DNA was a helix.
James Watson and Francis Crick (1953)	Worked out the structure of DNA. Their DNA model was a double helix, with its sides made of alternating sugar and phosphate groups, joined together by pairs of bases, like the rungs of a ladder.

Lesson plan

Step 1: Ask the class: Why do you look like your mum and dad? Direct students to **Activity 3.2** in the *Student Guide*.

Step 2: Open the digital link and watch the video as a class. Pause at each description of the contributions of key scientists to develop a ***Concept Map*** on the white board, with student help.

Step 3: Invite students to explore the remaining information in **Activity 3.2** and then refer them to the ***Notebook*** task. Agree on a time limit for the ***Notebook*** task.

Follow up: Invite students to share their creative responses with the class.

3.3 DNA extraction

Lesson outcomes

At the end of this activity students will be able to:

- extract DNA from dried peas
- explain the steps involved in the extraction of DNA.

What ideas might your students already have?

- most students will have a limited knowledge of DNA

Key vocabulary:

DNA, deoxyribonucleic acid, lipid, cell membrane, detergent, precipitate.

Equipment list

The CLASS will require:

- 200 mL dried green split peas
- 400 mL water
- ¼ tsp table salt
- blender.

Each GROUP will require:

- 250 mL beaker
- 100 mL beaker
- 6 mL dishwashing detergent (not concentrated)
- ice-cold methylated spirits
- 1 small strainer
- 1 test tube
- 1 glass rod
- 1 wooden skewer.

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider

- Ensure the methylated spirits is ice-cold (e.g. by placing it overnight in a closed container in the freezer)
- Extracted DNA can be kept in sample tubes containing alcohol
- As this is an Engage and Explore activity, it is not yet necessary to discuss the structure of DNA
- If you would prefer to extract DNA from strawberries or kiwi fruit, follow the method outlined in the downloadable Plant Energy Biology activity sheet 'Extract plant DNA' (http://plantenergy.edu.au/news/media/DNA_extraction.pdf).

Teacher content information:

This procedure involves:

- blending to break the cells apart
- filtering to remove large cell debris from the solution
- adding detergent to break open the cell and the nuclear membranes to release the DNA. The membranes contain lipids (fats) which the detergent binds with.
- precipitating the DNA from the solution by adding methylated spirits. As DNA precipitates, it clumps together and becomes visible to the naked eye. The added salt helps the DNA to precipitate and clump together.

A single DNA molecule is too small to see with the naked eye (or a light microscope). This procedure extracts DNA from many cells, so students see clumps of many molecules of DNA.

Lesson plan

Step 1: Ask students the following questions:

- Where is DNA found in a cell?
- Do you think we can see DNA without a microscope?

Explain that they will extract DNA from dried peas. Form small groups and invite them to collect their equipment.

Step 2: Blend the split peas, salt and water on high for 15 seconds. Provide each group with approximately 40 mL of the mixture.

Step 3: Students can follow the steps in their *Student Guide* and ***Notebook*** their answers to the questions.

Step 4: Conclude with a class discussion of the students' observations and ***Notebook*** answers.

Follow up:

Ask students to design a controlled experiment to optimise the amount of DNA extracted. E.g. test the effect of pea mass, different masses of salt, sources of DNA, types of detergent etc.

3.4 Big, bigger, biggest

Lesson outcomes

At the end of this activity students will be able to:

- describe the levels of organisation of the following structures – human body, cells, nucleus, chromosomes, genes and DNA
- understand that genes are sections of DNA that are responsible for inherited traits
- explain the term *heredity*.

What ideas might your students already have?

- Students may be familiar with the location of the nucleus and chromosomes in the cell, from earlier units.
- Students may recognise DNA and genes are involved in heredity, but will probably have a limited understanding of the mechanisms of heredity, and of the relationships between DNA, genes and chromosomes.

Key vocabulary:

Heredity, gene, gene testing, BRCA1 and 2 genes (**BR**east **CA**ncer tumour suppression genes 1 and 2), chromosome, DNA, cell, nucleus, trait, genome

Equipment list

Each STUDENT will require:

- Internet access
- *Science by Doing* ***Notebook***

Things to consider

- Students will require a Scootle Student login PIN to access the Scootle digital resource *Genes: introduction to genes* (L5918). For information on how to create a Learning Pathway and a Student login PIN see General Information – Scootle Resources.
- As this part of the unit introduces a number of new terms, you may wish to start a *word wall* in the classroom or ask students to start a glossary in their ***Notebooks***. The following links have some ideas for the use of word walls in science:
  - Tyson, K. (2013) *5 Easy Steps to Rockin' Word Walls* http://www.learningunlimitedllc.com/2013/07/5-steps-word-walls/
  - Jackson, J. and Narvaez, R. (2013) Interactive word walls http://c.ymcdn.com/sites/www.statweb.org/resource/collection/87BE2411-14C9-4AC7-883F-49C2A691379E/dGtRATk8TumE6TYnXxAc7rbg.pdf

Teacher content information:

- Chromosomes are located in the nucleus of a cell. They are thread-like structures made of DNA coiled around proteins. Human body cells each have 23 pairs of chromosomes (46 in total). Each chromosome has many genes along its length.
- DNA is the molecule responsible for inheritance.
- A gene is a section of DNA that carries the information for a particular trait (by coding for specific proteins).
- An organism's genome is its entire set of chromosomes/DNA.

Lesson plan

Step 1: Project **Activity 3.4** onto a class screen and read out the information on Angelina Jolie. Use a ***Think-Pair-Share*** strategy to discuss the following questions:

- What is heredity?
- What do you think of when you hear the term gene?

Step 2: Play the video to the class, then briefly discuss the key points (this video was also shown in **Activity 3.1**).

Suggested question/s:

- What does inheriting this breast cancer suppression gene mutation mean to Krystal?
- Apart from genes that cause disease, what other traits can genes control?
- What do you think genes look like?

Step 3: Invite students to complete the ***Notebook*** activity.

3.5 Lolly DNA

Lesson outcomes

At the end of this activity students will be able to:

- describe the components and structure of DNA
- create a model to represent the structure of DNA using the base-pairing rule.

Key vocabulary:

DNA, complementary, base, adenine, thymine, guanine, cytosine, nucleotide, phosphate, sugar.

Equipment list

The CLASS will require:

- 2-3 cm pieces of soft red and black liquorice (12 pieces of each colour, per student group) to represent the phosphate and sugar backbone of the molecule. (Note: extra lollies will be needed in **Activity 4.7**)
- A choice of four differently coloured lollies to represent the bases (minimum four of each colour per student group). E.g. Pascall's marshmallows, gummy bears or jelly beans.
- A choice of method for joining lollies together. E.g. several boxes of toothpicks or needles and thread.

Each GROUP will require:

- clean butcher paper
- large zip-lock bag
- disposable plate

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- Pair of food preparation disposable gloves
- internet access

Things to consider

- Students will require a Scootle Student login PIN to access the Scootle digital resource *Welcome to Genes: what is DNA?* (L5919). For information on how to create a Learning Pathway and a Student login PIN see General Information – Scootle Resources.
- Remind students there are just enough lollies for the activity; they can't eat them until another lesson.
- Check final models for: phosphate-sugar backbone, correct base-pairing and bonding of the bases to sugar molecules.
- The lolly models will be used in three activities, so you may wish to consider the timing of these lessons.
- The lolly model is added to in **Activity 3.7**. If supplies are limited, you may wish to use larger groups or alternative materials.

Teacher content information:

If the DNA double helix molecule was unwound, we could compare it to a ladder. The sides of the ladder are made of alternating phosphate and sugar groups. The rungs of the ladder join the sugar groups and contain pairs of bases. There are four different bases, and each will only pair with one other base. These *complementary base pairs* are:

- guanine (G) and cytosine (C)
- adenine (A) and thymine (T)

Lesson plan

Step 1: Discuss the information in **Activity 3.5** of the *Student Guide*. Explain that students will make a lolly model of DNA, which they can eat after a later lesson.

Step 2: Explain they must firstly learn how DNA is built. Invite students to complete the digital interactive in and then the ***Notebook*** tasks.

Step 3: Invite students to form groups (two to three) and to follow the instructions in the *Student Guide* to design and build their lolly models.

Step 4: As groups finish, check their models for accuracy before asking them to seal them in the labelled zip-lock bag.

Suggested question/s:

- Can you explain the parts of your model to me?
- What base does this coloured lolly represent?
- What base is it joined to?

Follow up:

The same lolly models are used in **Activity 3.6 Coding for proteins** and **Activity 3.7 Copying DNA for cell division**.

3.6 Coding for proteins

Lesson outcomes

At the end of this activity students will be able to:

- explain what DNA codons are and briefly describe their role in protein synthesis
- use a codon table to decode the sequence of amino acids coded for by a DNA molecule
- recognise that DNA can be used in identification e.g. of suspects from a crime scene.

What ideas might your students already have?

- Students should have an understanding of the structure of DNA (from **Activity 3.5**) before completing this activity.
- Students may have a superficial knowledge of the use of DNA in identification from popular television shows such as CSI.

Key vocabulary:

Adenine, cytosine, thymine, guanine, codon, protein, amino acid.

Equipment list

Each GROUP will require:

- lolly DNA model (from **Activity 3.5**)

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider

If large zip-lock bags have been used, students may be able to read their DNA model in the bag. If not, consider whether students will need disposable plates and food preparation gloves to handle the models.

Teacher content information:

The NSW Government's Centre for Genetics Education (CGE) produces genetics fact sheets to help individuals, families and health professionals better understand genetic health information, testing techniques and the impact genetics has on health and the community (http://www.genetics.edu.au/publications-and-resources/facts-sheets).

In particular, you might like background material about:-

DNA, Genes and Chromosomes (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-1-an-introduction-to-dna-genes-and-chromosomes)

Forensic, Paternity and Ancestry DNA Testing (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-17-forensic-paternity-and-ancestry-dna-testing)

Answers to discussion questions:

a) codon - CAG amino acid - Glutamine

b) codon - GTG amino acid - Valine

c) codon - CAA amino acid – Glutamine (Note – often several different codons code for a single amino acid.)

d) codon - TAA - STOP

codon - TAG - STOP

codon - TGA - STOP

g) You are now going to help solve a crime using your knowledge of DNA. A DNA sample has been collected from a revolver found at a crime scene. This DNA sample may help to identify the suspected murderer.

Your job is to work out what colour hair the DNA codes for. The murder suspect has naturally blond hair. Does the DNA from the weapon come from the suspect?

Use the codon table to find the amino acid sequence coded for by the gene for hair colour in the DNA sample. Match this sequence to one of the following, to identify what hair colour the DNA codes for. (**Note**: hair colour is really more complex than this.)

Methionine-Serine-Threonine-Glutamine-Phenylalanine Red hair

Methionine-Serine-Threonine-Histadine-Leucine Blond hair

Methionine-Proline-Threonine-Histadine-Phenylalanine Black hair

Methionine-Proline-Threonine-Glutamine-Leucine Brown hair

DNA sample	A T G T C A A C T C A A T T C T A G					
Codon sequence	ATG	TCA	ACT	CAA	TTC	TAG
Amino acid sequence	Methionine	Serine	Threonine	Glutamine	Phenylalanine	STOP
Hair colour	Red hair					

Lesson plan

Step 1: Project the *Student Guide* onto the class screen and ask students to review the information in **Activity 3.6**. If a word wall or glossary is being used, invite students to add any new words (e.g. protein, codon).

Step 2: Show students how to use the Codon table to find which amino acid each codon codes for.

Step 3: Ensure students are seated with their groups from the last lesson and allow one member to collect their lolly DNA model. Invite students to begin the discussion questions in their ***Notebooks***. Circulate to ensure students are correctly interpreting the codon table.

Follow up:

Ask students to:

- find a possible DNA sequence for the murder suspect (blond hair)
- make up a sequence of DNA with 21 bases for their Learning Partner to translate into an amino acid sequence
- find out about forensic DNA analysis from Learn.Genetics (http://learn.genetics.utah.edu/content/science/forensics/)

3.7 Copying DNA for cell division

Lesson outcomes

At the end of this activity students will be able to:

- explain why DNA is replicated prior to cell division
- demonstrate DNA replication.

What ideas might your students already have?

- Students should be aware of the basic process of mitosis from the year 8 unit *From Little Things Big Things Grow.*

Key vocabulary:

DNA replication, DNA strands, complimentary bases, cell division.

Equipment list

Each GROUP will require:

- lolly DNA model (from **Activity 3.5**)
- extra supplies of lollies and equipment (as per **Activity 3.5**)

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- pair of food preparation disposable gloves

Things to consider

- Students should remain in the same groups as in **Activity 3.5**.
- Consider the timing of this lesson – students eat their lolly models afterwards.

Teacher content information:

Before cells divide by mitosis, the DNA is first copied through the process of *DNA replication*:

1. The DNA unzips.
2. Each of the exposed strands has new complementary bases added along its length.
3. Two new molecules of DNA are formed, identical to the original DNA molecule. Each new molecule is made up of one old and one new strand.

Because of this replication of the cell's DNA, when cells divide, each new cell can get a complete set of chromosomes/DNA.

Lesson plan

Step 1: In a class discussion, remind students that cells divide to make new cells.

Suggested question/s:

- How have you grown from a single-celled egg to a multi-celled teenager?

Step 2: Ask the class to predict what happens to the amount of DNA when one cell divides into two new cells? Use a show of hands to record on the whiteboard whether they think each new cell will have half, or the same amount, of DNA. Explain they will find out by modelling what happens to the DNA in a cell before it divides.

Step 3: Invite students to reform their groups from the previous lesson. Project the *Student Guide* and show the photo of a cell dividing into two cells. Step the class through the process of DNA replication.

Step 4: Invite student groups to unzip their lolly molecules and simulate DNA replication.

Step 5: Conclude with a class discussion. Remind students they have modelled what happens to DNA before a cell divides. Again, use a show of hands to record on the whiteboard whether students think the amount of DNA is halved or stays the same after a cell divides.

Suggested question/s:

- Why is DNA replication an important process in cells?

Step 6: Invite groups to enjoy their lolly DNA.

3.8 How do we grow?

Lesson outcomes

At the end of this activity students will be able to:

- list situations in which mitosis occurs
- describe mitosis as a type of cell division producing two genetically identical cells
- recall the stages of mitosis and the order they take.

What ideas might your students already have?

- Students should be aware of the basic process of mitosis from the year 8 unit *From Little Things Big Things Grow.*

Key vocabulary:

Cell division, mitosis, chromosomes, chromatids, cell equator, spindle fibres, cell poles, interphase, prophase, metaphase, anaphase, telophase.

Equipment list

Each GROUP will require:

- optional: props for role play of chromosomes: e.g. pool noodles, paired pieces of rope of different lengths, lengths of plastic tubing, card for labels etc.

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebook****.*

Teacher content information

Although often depicted in a series of distinct stages it is important to remember mitosis is a continuous process involving division of the nucleus. The stage between cell divisions, when the DNA is replicated, is referred to as interphase. The main stages of mitosis are often described as:

- prophase
  - DNA coils up and the (doubled) chromosomes become visible
- metaphase
  - nuclear membrane disappears, chromosomes line up across the centre (equator) of the cell
- anaphase
  - chromosomes are pulled apart, single chromosomes move to opposite poles of the cell
- telophase
  - nuclear membrane reforms around the two, new, genetically identical nuclei and the cell starts to divide.

It is sufficient for students to recall the process/stages of mitosis, the names of stages are unnecessary.

Mitosis occurs to:

- replace cells and repair damaged tissue
- grow and develop (multicellular organisms)
- reproduce asexually.

Lesson plan

Step 1: Begin with a class discussion. Project **Activity 3.8** on a screen and refer to the questions:

- How did you grow from a single fertilised egg into a human with trillions of cells?
- How does your body repair itself when you graze your knee?

Step 2: Invite students to explore the rest of the resources and then to complete the ***Notebook*** table of the stages of mitosis.

Step 3: Form groups of four and agree on the time needed to prepare role plays. Explain presentations should not exceed three minutes.

Step 4: Role plays can either be presented to the class, or to another group, depending on the time available. Ask each group to provide constructive feedback to another group on their presentation.

4.1 Making babies

Lesson outcomes

At the end of this activity students will be able to:

- identify the organs of the human reproductive systems
- relate the organs of the human reproductive systems to their functions
- recognise genetic information is passed to offspring from both parents at fertilisation.

Key vocabulary:

Testicle, sperm duct, vas deferens, prostate gland, penis, epididymis, urethra, seminal vesicle, semen, ovary, cervix, vagina, fallopian tube, oviduct, uterus, womb, vasectomy.

Equipment list

The CLASS will require:

- **Making Babies Bingo PowerPoint** (download from Teacher Guide)
- **Activity sheet 4.1 Making Babies Bingo Cards** (download from Teacher Guide)

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebook***
- 20-25 bingo chips (or one white board marker and tissues for laminated cards)

Things to consider

- Review the digital resources if you need a refresher on the male and female human reproductive systems.
- The *Reproductive Cycle* interactive requires a *Flash* player.
- There are two bingo cards on each page; you may wish to laminate the page before cutting in two.
- If playing multiple games of bingo, start each at a different slide in the PowerPoint.
- Consider providing some reward for students that win each game of bingo.

Lesson plan

Step 1: Introduce the reproductive system using the context of inheritance.

Suggested question/s:

- Why do we look like our parents?
- How did we end up with their genes?

Step 2: Project the *Student Digital* and refer to the image of a gene to remind students genes are sections of DNA. Discuss the inheritance of genes/DNA from both parents at fertilisation.

Step 3: Invite students to explore the links to *Female Reproductive System* and *Male Reproductive System* and complete the ***Notebook*** tables.

Step 4: Provide each student with a *Making Babies Bingo* card and bingo chips (or a whiteboard marker and tissue if the cards have been laminated).

Step 5: Project the bingo PowerPoint slides as students mark the corresponding term on their cards. There may be more than one image/term for each organ. The centre square is a free, so can be covered straight away.

Step 6: The first student to mark five squares in a row (horizontally, vertically, or diagonally) wins the round. The winner must read out their answers correctly to win the game.

Step 7: Allow students sufficient time to explore The *Reproductive Cycle* interactive (Requires *Flash*) and develop explanations for how contraceptives work.

4.2 Making sex cells with meiosis

Lesson outcomes

At the end of this activity students will be able to:

- recognise genetic information passed to offspring is from both parents by meiosis and fertilisation
- describe the stages of meiosis
- describe meiosis as a type of cell division that produces gametes with half the number of chromosomes of the parent cell, and that are genetically unique.

What ideas might your students already have?

- Students will be familiar with cell division by mitosis and may confuse the two types of cell division.

Key vocabulary:

Testicle, sperm duct, vas deferens, prostate gland, penis, epididymis, urethra, seminal vesicle, semen, ovary, cervix, vagina, fallopian tube, oviduct, uterus, womb, vasectomy.

Equipment list

Each GROUP will require:

- 4 different colours of plasticine
- 1 sheet of butcher paper
- extra paper and scissors/sticky labels
- phone or camera to photograph plasticine models.

Each STUDENT will require:

- internet access
- *Science by Doing* ***Notebook***

Things to consider

Although often depicted as a series of distinct stages, remember that meiosis is a continuous process. It is sufficient for students to recall the process/stages of mitosis, the names of stages are unnecessary at this level.

Find fun ways for students to distinguish meiosis from mitosis:

- mei**O**sis happens in **O**varies,   mi**TO**sis happens in **To**es
- m**E**i**OS**is   **E**ggs →**O**ne set of chromosomes ← **S**perm
- mi**T**osis   **T**wo cells and sets of chromosomes.

Teacher content information

The correct order for the interactive of the stages of meiosis is shown below (with further details):

1. Original parent cell

Human somatic (body) cells have a **di**ploid number of chromosomes (**two** sets of chromosomes = 23 pairs).

2. DNA is replicated

Each chromosome now has two chromatids.

3. Similar chromosomes pair up

These are homologous chromosomes: pairs of chromosomes (one from the mother and one from the father) that are similar in appearance and have the same genes, in the same order.

4. Crossing over: sections of DNA are swapped

5. Homologous pairs of chromosomes line up in the middle of the cell

The orientation of homologs occurs randomly, either one could end up on a particular side of the cell equator. Their random orientation affects how the genetic information from both parents is distributed to the gametes in Step 6.

6. Cell splits into two unique daughter cells

One homolog is pulled to one pole and the other homolog to the other. The cell then splits into two unique daughter cells.

7. Chromosomes separate and both cells divide making four unique cells, each with half the number of chromosomes.

Chromosomes consist of pairs of chromatids, some that have experienced crossing over. Chromatids separate and both cells divide, making four unique cells, each with half the number of chromosomes (haploid).

Lesson plan

Step 1: Project the *Student Digital* to introduce students to the idea that sex cells (gametes) have half the number of chromosomes of body cells, and why.

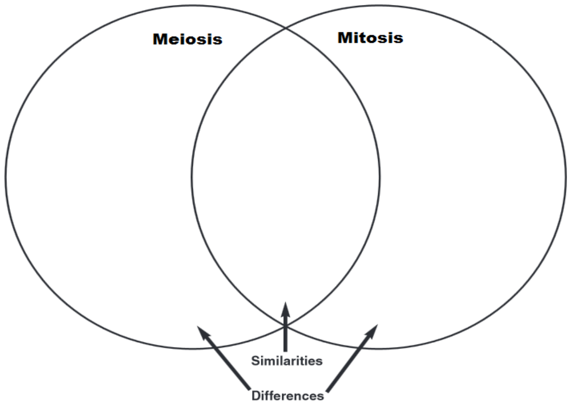
Step 2: Show the video to the class, or invite students to watch it individually (if headphones are available).

Step 3: Ask students to sequence the stages of meiosis.

Step 4: Form groups of four and agree on a time to complete the ***Notebook*** activities.

Step 5: Ask students to begin the Venn Diagram activity and to discuss their answers with a ***Learning Partner***. Remind students they are only comparing what happens to the chromosomes/cells, and need not worry about the names of stages and finer cell details.

Step 6: Draw a large Venn diagram on the whiteboard as below and invite students to step up and add one item to it.



4.3 Why are we all different?

Lesson outcomes

At the end of this activity students will be able to:

- explain different sources of variation (genetic and environmental)
- recognise sexual reproduction increases the genetic variation in a population.

What ideas might your students already have?

Students will probably know variation can arise from both genetic and environmental factors, but may not understand the mechanisms behind this variation.

Key vocabulary:

Environment, karyotype, meiosis, randomly, melanocytes, melanin, sickle cell disease, sexual reproduction, fertilisation, mutation, widow's peak, crossing over, gametes.

Equipment list

Each STUDENT will require:

- *e-Notebook* or **Activity sheet 4.3 Anticipation guide** (download from Teacher Guide)
- internet access
- *Science by Doing* ***Notebook****.*

Things to consider

- Although students should work independently, they will feel more confident in their responses if allowed to discuss their answers with a ***Learning Partner***.

Teacher content information

In exploring similarities and differences in families the question is raised - 'Where does the variation come from?' The popups in the family photo describe four forms of variation:-

- Environment – our environment can influence many of our inherited characteristics. E.g. sun exposure can alter your skin tone.
- Independent assortment of homologous chromosomes during meiosis produces a variety of sperm or eggs (gametes)
- Mutations – all genetic variation originally came from mutation, where a DNA sequence was altered or incorrectly copied.
- The randomness of which sperm meets which egg – each parent produces a variety of different sex cells and the fertilised egg is the result of one of trillions of possible genetic combinations.

The other important form of variation is caused by crossing over. This concept and its significance is best explained once students have studied linkage in Unit 3 of the senior secondary curriculum.

Lesson plan

Step 1: Project the image of a family in **Activity 4.3** and read out the questions underneath it. Brainstorm why the family members vary.

Suggested question/s:

- Can you explain why the baby's skin is darker than that of his siblings?

- Why does hair colour vary so much in the family?
- What makes some kids in this family get blue eyes and others get brown eyes?

Step 2: Ask students to download the ***e-Notebook*** or distribute ***Activity Sheet 4.3 Anticipation Guide.***

Step 3: Read out the first statement:-

'Organisms only vary in height because their environment differs.'

Tell students to look at the image of the family as they consider whether this statement is true or false. They should put their answer in the *Before reading* column.

Step 4: Keep the image projected while students complete the *Before reading* column of the ***Anticipation Guide***. When they have finished, you may wish to survey responses, using a show of hands.

Step 5: Invite students to now click on each family member and complete the ***Notebook*** activity.

Step 6: Conclude with a class discussion about variation. You may wish to survey responses to the *After reading* section of the ***Anticipation Guide***, using a show of hands. Ask students to discuss in pairs and ***Notebook*** how their ideas about variation changed.

Suggested question/s:

- Can you tell me some of the ways that sexual reproduction increases variation?
- Did your ideas about what a mutation is, change? How?

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4.4 Boy or girl?

Lesson outcomes

At the end of this activity students will be able to:

- describe sex determination in humans, including the role of the SRY gene
- acknowledge that sex determination systems can vary between different groups of vertebrates
- recognise the contribution of Australian scientists towards our current understanding of sex determination
- predict the effect of climate change on species with temperature-dependent sex determination.

Key vocabulary:

Karyotype, SRY gene, XY system, temperature dependent sex determination, sex chromosome, ZW system.

Equipment list

Each STUDENT will require:

- internet access
- headphones (optional)
- *Science by Doing* ***Notebook****.*

Things to consider

- Consider whether students should watch the video as a class or individually. Watching individually will require headphones, but allows students to learn at their own pace.

Teacher content information

Humans have 23 pairs of chromosomes in each body cell (46 in all). The chromosomes in these pairs are similar in size and shape, except for the 23rd pair, which consists of the sex chromosomes:

- Females have two similar X chromosomes (XX genotype).
- Males have an X chromosome and a much smaller Y chromosome (XY genotype).

Gametes (sex cells) only have one set of chromosomes (23 chromosomes), so each sex cell has only one sex chromosome:

- Eggs/ova contain one X chromosome.
- Sperm have either an X or a Y chromosome. So when chromosomes from the egg and sperm combine at fertilisation, the sex chromosome (X or Y) in the sperm from the father determines the sex of the baby (XX or XY).

The Y chromosome has a gene called the SRY gene which makes an embryo male. It was discovered in 1990 by Andrew Sinclair, one of Prof Jenny Graves' PhD students. Much of our understanding of sex chromosomes in various animal groups comes from Prof Graves' work.

ZW sex determination

Birds (and many reptiles) have the opposite system to humans - the female has two different sex chromosomes (ZW), while males have two of the same sex chromosome (ZZ).

Temperature-dependent sex determination

The sex of some reptiles is determined by the temperature of the incubating eggs, or a combination of sex chromosomes and temperature.

Lesson plan

Step 1: Introduce the topic of sex determination.

Suggested question/s:

- What made you develop into a male or female?
- What about other species? Is sex always determined in the same way?

Step 2: Discuss or ask students to review the information on karyotypes and sex chromosomes in the *Student Guide*. If a word wall or glossary is used, invite students to add the terms karyotype and sex chromosome.

Step 3: Invite students to watch the video on sex determination and to work with a ***Learning Partner*** to complete the ***Notebook*** questions.

Step 4: Discuss student responses as a class.

4.5 Dominant and recessive genes

Lesson outcomes

At the end of this activity students will be able to:

- describe some examples of simple Mendelian traits
- recognise we generally inherit two versions (alleles) of each gene – one from each parent
- predict the phenotype resulting from different combinations of dominant and recessive genes.

Key vocabulary:

Gregor Mendel, trait, allele, gene, dominant, recessive, genotype, phenotype, widow's peak, cleft chin.

Equipment list

The CLASS will require:

- **Activity Sheet 4.5 Numbers and percentages for inherited traits** (download from Teacher Guide)

Each STUDENT will require:

- *e-Notebook* or **Activity Sheet 4.5 Trait survey** (download from Teacher Guide)
- internet access
- headphones (optional)

Things to consider

- Headphones are not essential for the interactive game; you may wish to ask students without headphones to mute the sound.

Teacher content information

We generally inherit two versions (alleles) of each gene – one from each parent. In simple Mendelian inheritance, the alleles can be either dominant or recessive. Dominant alleles are shown by a capital letter, recessive by a lower case letter. The traits due to dominant alleles are always expressed, even when a recessive allele is also present (e.g. either WW or Ww produce the dominant trait widow's peak hairline). Traits due to recessive alleles are only expressed when there are two copies present (e.g. ww).

Inheritance does not always follow simple Mendelian rules. Many inherited traits are the result of multiple genes or alleles. Some sources suggest the common examples used in this activity may not necessarily follow a simple dominant/recessive pattern of inheritance.

Lesson Plan

Step 1: Project an image of the widow's peak hairline from the *Student Guide*. Ask students to turn to the person next to them to determine whether they have a widow's peak or straight hairline. Explain that this is an example of an inherited trait. Students have inherited two copies of the gene for this trait, one from each of their parents.

Step 2: Explain to students that to understand how traits like widow's peak are inherited, they will explore a cartoon about the 'father of genetics', Gregor Mendel. Give students time to read the comic in the *Student Guide*.

Suggested question/s:

- What did Mendel mean by the terms *dominant* and *recessive*?
- Why did short pea plants disappear in Mendel's first generation? (all offspring inherited a copy of the dominant T allele)
- What combination of alleles produced the recessive short trait? (tt)

Step 3: Refer students to the image of the widow's peak in the *Student Guide* to work out their genotype and phenotype for hairline. Tell students that the phenotype 'straight hairline' is a recessive trait, so if they have a straight hairline, both alleles must be recessive (ww).

Step 4: Ask students to open **Activity 4.5** in their *e-Notebook* or distribute **Activity Sheet 4.5 Trait survey**. Invite students to discuss each trait with their ***Learning partner*** and complete their own survey.

Step 5: Project **Activity Sheet 4.5 Numbers and percentages** for inherited traits on the board and tally the group results. Ask students to compute the class percentages.

Step 6: Ask students to ***Notebook*** their responses to the discussion questions.

Step 7: Invite students to click on the digital link and play *Pass the Genes, Please*.

Follow up:

The *Find out more* section of the *Student Digital* provides links to extra information on more complex inheritance including incomplete dominance, codominance, and polygenic inheritance.

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4.6 Heredity – what's the chance?

Lesson outcomes

At the end of this activity students will be able to:

- draw and complete Punnett squares for simple Mendelian crosses
- predict the ratio of offspring genotypes and phenotypes from crosses involving dominant/recessive gene pairs.

What ideas might your students already have?

- Students should have an understanding of dominant and recessive genes.

Key vocabulary:

Allele, gene, dominant, recessive, trait, genotype, heterozygous, homozygous, phenotype, Punnett square.

Equipment list

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- internet access
- headphones (optional)
- **Activity Sheet 4.6 Crossword puzzle** (download from Teacher Guide)
- **Activity Sheet 4.6 Genetic quiz (**optional alternative to the digital quiz, download from Teacher Guide)

Things to consider

Ensure students understand that Punnett squares do not show individual offspring, rather they help to predict the **probability** of offspring inheriting certain traits.

You may wish to answer the first few questions from the digital quiz before asking students to complete the quiz. This will reinforce the concepts and demonstrate the **Hints** function that appears after errors.

Although students should complete the quiz independently, they will feel more confident if allowed to discuss their answers with a ***Learning Partner***.

Teacher content information

An early British geneticist, Reginald Punnett, devised the Punnett square to calculate the potential genetic combinations (genotypes) of children from the genotypes of the parents. It is also used to predict the probability of each of the genotypes of children occurring.

Lesson Plan

Step 1: Project the first page of **Activity 4.6** in the *Student Guide* and work through the introduction to Punnett squares.

Suggested question/s:

- How accurately can a Punnett square predict the characteristics of offspring?

Step 2: Ask students to work with a ***Learning Partner*** and complete both possible Punnett squares for widow's peak in their ***Notebooks***.

Step 3: Distribute **Activity sheet 4.6 Crossword puzzle** and encourage students to revise the *Student Guide* to find the words and their spelling.

Step 4: Direct students to the multiple *choice Genetics quiz,* modelling if necessary the first couple of questions. Note - the digital quiz provides feedback to student responses. Alternatively, provide students with **Activity Sheet 5.6 Genetics quiz**.

Step 5: Project each question of the quiz and assess where students are having difficulty.

Step 6: Direct students to the *Create your own animal game*. Ensure they firstly read the *Procedure* section (scroll down in the left-hand window of the game).

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5.1 What's the problem with mutations?

Lesson outcomes

At the end of this activity students will be able to:

- describe mutations as changes in DNA or chromosomes
- outline factors that cause mutations.

What ideas might your students already have?

Students often believe that mutations are always harmful.

Key vocabulary:

Insertion mutation, deletion mutation, substitution mutation, Down syndrome, Human papillomavirus (HPV), Prof Ian Frazer.

Equipment list

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- internet access

Teacher content information

Mutations involve changes to DNA:

- insertion mutation – one or more extra base pairs are inserted into the DNA sequence. This may shift the reading of codons and change which amino acids are sequenced.
- deletion mutation – one or more base pairs are removed from the DNA sequence. This may shift the reading of codons and change which amino acids are sequenced.
- substitution mutation – a base is replaced by a different base in the DNA molecule. This may only alter one amino acid in the sequence.

Larger-scale errors can happen when chromosomes don't separate properly during gamete formation. People with Down syndrome are born with an extra copy of chromosome 21.

The NSW Government's Centre for Genetics Education (CGE) produces genetics fact sheets to help individuals, families and health professionals better understand genetic health information, testing techniques and the impact genetics has on health and the community (http://www.genetics.edu.au/publications-and-resources/facts-sheets).

In particular, you might like background material about:-

Variations in the Genetic Code (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-2-variations-in-the-genetic-code)

Lesson Plan

Step 1: Assess students' understanding of mutations through a quick brainstorming session, recording responses on the whiteboard.

Suggested question/s:

- What do you think when I say the word mutation?

Step 2: Explain that DNA in a cell can change and this can affect an organism's characteristics. Changes to the DNA in genes are called mutations.

Step 3: Invite students to ***Notebook*** factors that can cause changes to DNA as they explore the popup boxes in *What causes changes to DNA?*

Step 4: Explain students will discover ways DNA can change through mutation. Direct them to the ***Notebook*** activity *Exploring mutations*.

Step 5: If time permits, students can explore the *Find Out More* section for examples of harmful and benign mutations.

Step 6: Refer to the brainstorming notes from Step 1 and ask students to reflect on their learning about changes to DNA.

Suggested question/s:

How have your ideas about mutations changed since the beginning of the lesson?

5.2 Family pedigrees

Lesson outcomes

At the end of this activity students will be able to:

- represent inheritance of a simple dominant/recessive characteristic through generations of a family, using a pedigree chart.

What ideas might your students already have?

Students will be familiar with family trees, but will probably not be aware of the use (and format) of pedigree charts to track the family inheritance of a trait.

Key vocabulary:

Pedigree, carrier, Huntington’s disease, dwarfism (achondroplasia), cystic fibrosis, albinism.

Equipment list

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- internet access
- **Activity sheet 5.2 My family pedigree** (download from Teacher Guide)
- large sheet of A3 paper or poster board
- coloured markers
- ruler

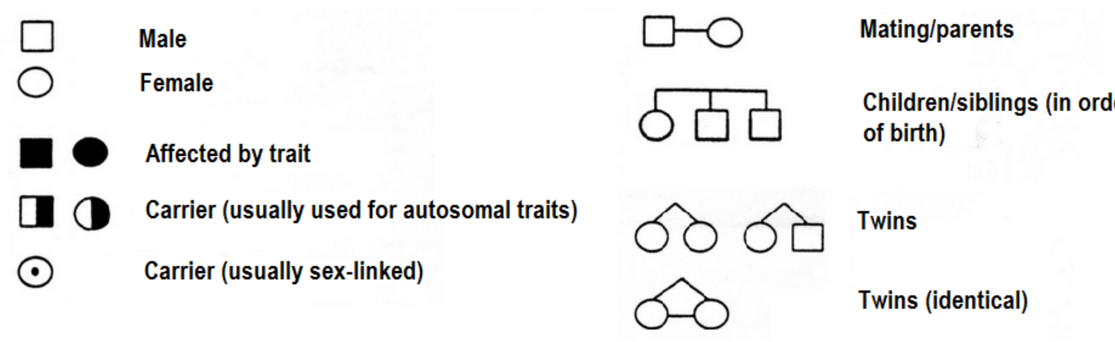
Things to consider

In this activity teachers should be sensitive to students who are adopted, live with guardians, or are in family situations where this kind of activity is not possible.

- If students can’t contact a family member, photographs may be useful for determining traits.
- Suggest that students sketch an outline of their pedigrees before creating their final versions.

Teacher content information

Some standard symbols on pedigree charts:



Huntington's Disease (HD) is a brain disorder that affects a person's ability to think, talk, and move. Symptoms will not usually appear until the person is between 35 and 55 years of age. From the onset of symptoms, people usually have a life expectancy of 10 to 25 years. Huntington's disease is inherited in an autosomal dominant pattern.

This means that everyone who inherits the faulty gene will eventually get the disease. A parent with a mutation in the HD gene has a 50 percent chance of passing the disease to their children.

Cystic fibrosis is a genetic disorder that affects the respiratory and digestive systems. Cystic fibrosis is a recessive disorder, which means that both parents must pass on the defective gene for any of their children to get the disease. If a child inherits only one copy of the faulty gene, he or she will be a carrier. Carriers don't actually have the disease, but they can pass it on to their children.

Achondroplasia is a form of short-limbed dwarfism. The average height of an adult male with achondroplasia is 131cm and the average height for adult females is 124 cm. Achondroplasia is inherited in an autosomal dominant pattern.

Albinism is an inherited genetic condition that reduces the amount of melanin pigment formed in the skin, hair and/or eyes. Albinism occurs in all racial and ethnic groups throughout the world. In Australia, approximately one in 17,000 people have some type of albinism. A common myth is that people with albinism have red eyes. Although lighting conditions can allow the blood vessels at the back of the eye to be seen, which can cause the eyes to look reddish or violet, most people with albinism have blue eyes, and some have hazel or brown eyes. Albinism is inherited in an autosomal recessive pattern. Both parents must carry the albinism gene and pass it on to their child.

Lesson plan

Step 1: About a week before the lesson, inform students they will create a family tree that shows the inheritance of a trait in their family. To do this, they will need to survey their family for the trait. Distribute **Activity sheet 5.2 My family pedigree**, and ask students to survey their family for one of the traits listed on the sheet. Ensure students are clear on what the traits look like and stress when they will need to bring their survey data into class.

Step 2: Discuss as a class or invite students to explore the information on family pedigrees in the digital activity. Invite some students to draw the pedigree symbols for: male, female, parents, children and an affected male on the whiteboard, then ask the class to create a table in their ***Notebooks*** for the symbols.

Step 3: Project the pedigree chart shown in the *Student Guide* to explain the type of pedigree chart they will make for their own families based on the survey they have completed.

Step 4: As students complete their pedigrees, direct them to the multiple choice quiz in the ***Notebook*** activity.

Step 5: Ask students to send you their quiz results, for **formative assessment** of their progress and to assess the need for further practise of the skills.

Follow up:

Collect pedigree charts and quiz results as a **formative assessment** and review them to give students feedback on their skills and understanding.

5.3 Sex-linked inheritance

Lesson outcomes

At the end of this activity students will be able to:

- predict ratios of offspring genotypes and phenotypes in crosses involving genes that are sex-linked
- represent inheritance of a sex-linked characteristic through generations of a family using a pedigree chart.

Key vocabulary:

Sex-linked.

Equipment list

Each PAIR will require:

- **Activity sheet 5.3 Sex-linked inheritance** (download from Teacher Guide)
- Scissors
- Two cups
- Marker pen

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- internet access

Things to consider

- If a student suspects they may be colour blind, clarify that many people live normal lives with the condition.

Teacher content information

Sex-linked traits tend to be more common in one gender. In humans, red-green colour blindness is more common in males. This is because the condition is caused by a recessive gene on the X chromosome. Males only have one X chromosome, so if they inherit a single copy of the gene for colour blindness, they will have the condition. Females have two X chromosomes, so they can carry the colour blindness gene without being colour blind if they have a dominant normal gene on their second X chromosome.

Further information on colour blindness is available at:

https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/colour-blindness

http://www.colourblindawareness.org/colour-blindness/

The NSW Government's Centre for Genetics Education (CGE) produces genetics fact sheets to help individuals, families and health professionals better understand genetic health information, testing techniques and the impact genetics has on health and the community (http://www.genetics.edu.au/publications-and-resources/facts-sheets). In particular, you might like background material about:- Haemophilia (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-52-haemophilia)

Lesson plan

Step 1: Project the colour blindness test image from the *Student Guide*.

Suggested question/s:

- What do you see when you look at this image?

Explain that most people see '@'. People who are red-green colour blind do not see the '@'. Discuss the information on sex-linked diseases in the *Student Guide*.

Step 2: Explain that students will discover patterns in the way colour-blindness is inherited by 'making babies' from a fictitious couple: Anne and Callum. Students will model what happens to Anne and Callums' sex chromosomes during meiosis and fertilisation. Refer students to the activity in their *Student Guide.*

Step 3: Form pairs and invite them to collect equipment for the modelling activity. Ensure that students have the correct sex chromosomes in each cup (Anne – X^N and X^n, Callum – X^N and Y) before making each baby.

Step 4: When students have completed the discussion questions in their ***Notebooks*** allow them to proceed to the digital activity.

Step 5: Summarise by reviewing the ***Notebook*** tasks as a class.

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5.4 Cleverly used genes?

Lesson outcomes

At the end of this activity students will be able to:

- describe examples of biotechnology/gene technology (genetic testing, GM crops, and IVF with embryo selection)
- discuss advantages and disadvantages of the use of biotechnology.

What ideas might your students already have?

Students may have strong opinions about the use of gene technology, but have limited understanding of the science (and the full range of issues) behind it.

Key vocabulary:

Gene technology, preimplantation genetic diagnosis (PGD), in vitro fertilisation (IVF), genetic modification, gene test.

Equipment list

Each GROUP will require:

- *Story card, Information cards* and *Issue cards* for one or more of the biotechnologies:
- **GM crops** (download from Teacher Guide)
- **Genetic testing** (download from Teacher Guide)
- **IVF with embryo selection** (download from Teacher Guide)

Each STUDENT will require:

- **Activity sheet 5.4 Top issues** (download from Teacher Guide or download the ***e-Notebook***)

Things to consider

- Download and print the *Story cards, Information cards* and *Issues cards*. Consider printing on to thick card and laminating the cards to make a durable resource. Each page of information cards can be folded in half lengthways, then cut into two before laminating.
- To cover the material in one double lesson, distribute the scenarios evenly between groups (copy two sets of cards for each scenario). The recommended group size is four-to-five students.
- Alternatively, depending on the time available, you may wish to cover each scenario in a separate lesson (give all groups the same scenario for discussion). This allows students to directly cover all three examples.

Teacher content information

The NSW Government's Centre for Genetics Education (CGE) produces genetics fact sheets to help individuals, families and health professionals better understand genetic health information, testing techniques and the impact genetics has on health and the community (http://www.genetics.edu.au/publications-and-resources/facts-sheets).

In particular, you might like background material about:-

Breast and Ovarian Cancer and Inherited Predisposition (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-32-breast-and-ovarian-cancer-and-inherited-predisposition)

Genetic and Genomic Testing (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-15-genetic-and-genomic-testing)

Ethical Issues in Human Genetics and Genomics (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-19-ethical-issues-in-human-genetics-and-genomics)

Pre-Implantation Genetic Diagnosis (PGD) (http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-29-preimplantation-genetic-diagnosis-pgd)

Lesson plan

Step 1: Explain *Gene Tech Check* is a card-based activity, designed to encourage discussions about issues associated with gene technology. In small groups, students will discuss the issues arising from three character-based scenarios. The stories and characters are fictitious, but all are based on accurate and scientific information. The questions on the cards do not have simple, or definite, answers. This is an opportunity to discuss the issues and gain an understanding of the technology.

Step 2: Divide the class into groups of four-to-five students. Allocate students to groups or get them to form their own. Distribute a *Story card* to each group.

Step 3: Invite students to read the *Story card* together, along with quotes from the characters on the card. Once the group has read and understood the story, they should discuss initial reactions to the question on the card. Circulate to ensure students understand what they are doing and prompt them to answer the question.

Step 4: Now give each group the set of *Information cards*. Each member will read each card. Groups should continue their discussion of the scenario, based on the new information.

Step 5: After about 15 minutes provide each group with the *Issue cards*. Students should take it in turns to pick up an *Issue card* and share it with the group. Groups should discuss each issue before proceeding to the next card. Remind the participants to use their **Activity sheet 5.4 Top issues** or ***e-Notebook*** to record the top two issues identified in each scenario and the group's views.

Step 6: Encourage students to wind down their discussions and agree on two issues to share with the class. If students are nervous about speaking in front of the class, encourage groups to nominate a speaker. Invite groups to present their information to the class. Record the issues on a whiteboard and ask students to ***Notebook*** ideas from other groups. If there is time, lead a discussion about the issues.

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5.5 Sample test

A sample summative test and marking scheme have been developed and are available to teachers from *Science by Doing* at sbd@science.org.au. Both are editable versions so you can adapt them to your students' needs.

Note - *Science by Doing* provides sample assessment items and whilst every effort has been made, the security of these items cannot be guaranteed. *Science by Doing* encourages teachers to modify the items to suit individual teaching programs.

Acknowledgements

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This resource was originally written in 2015 by Dr Rosalind Johnston and Mr Jef Byrne.

This resource was revised in 2018 by Jef Byrne and Dr Jim Woolnough.

Science by Doing would like to thank Spinks and Suns for the design and development of this resource.

Acknowledgement of assistance

The following people also assisted in the production of this resource:

Ms Bronwyn Terrill
Paula Lammers
Professor Jenny Graves AO FAA, La Trobe University
Dr Clare Holleley, University of Canberra
Professor Stephen Sarre, University of Canberra
Mr Ian Hart, Peace Mountain Productions

Funding Acknowledgement

Science by Doing is supported by the Australian Government.

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Evolution and Heredity, Lesson Plans: ISBN 978 0 85847 582 3

Published by the Australian Academy of Science
GPO Box 783
Canberra ACT 2601
Telephone: 02 62019400

www.science.org.au

Click **here** for a full version of unit acknowledgements and sources or logon to www.sciencebydoing.edu.au.

Last modified: March 2019

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