PRIMED
Teacher resource

Year

10

Science

Department of **Primary Industries and Regional Development**
Department of **Training and Workforce Development**
Department of **Education**
GOVERNMENT OF WESTERN AUSTRALIA

PRIMED

Teaching guide: WA primary producers – solving the big issues
Resources overview

PRIMED mission

To increase student understanding of agriculture, fisheries, fibre, forestry and food (primary industries) careers to enable Year 7–10 students to make informed career-pathway choices.

About the resource set

This series of activities challenges students to engage with the *Western Australian Science Curriculum* by focusing on balanced and sustainable ecosystems in Western Australian food and fibre production primary industries.

Through this process, students can gain a deeper understanding of the complexities of the biological and physical world, and how we interact with it to sustainably produce essential food and fibre.

Year 10 SCIENCE

Curriculum links

This resource set is designed to be a learning pathway for Year 10 Science students after they have already completed their course on genetics and evolution. It enables students to elaborate on their understanding of the *Western Australian Curriculum* **Biological Sciences** content descriptions:
- transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)
- the theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (ACSSU185)

It also engages students with the **Science as a human endeavour** content descriptions:
- Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE192)
- People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE194)
- Values and needs of contemporary society can influence the focus of scientific research (ACSHE230)

It further allows development of the **Science Inquiry Skills** integral to the *Western Australian Science Curriculum*.

Resource set structure

The resource set is structured around constructivist learning principles using the 5E model: engage, explore, explain, elaborate and evaluate. It is designed to be flexible so that teachers can use all or parts of the resource that they consider appropriate for their students.

With this approach:
1. Students' interest and minds are **engaged** in thinking about the 'wicked problems' of climate change, food security and biosecurity. Using the context of Western Australia (WA) primary production, they examine how the revolution in selective breeding and genetic technologies is enabling WA primary producers to address these issues.

2. Using examples from WA primary production, students **explore** genetic inheritance patterns such as:

   - cross pollination of wheat varieties
   - investigation of traits in agricultural plants such as albino barley
   - GM canola.

3. Students **explain** the basic principles of how the variation within agricultural plants and animals is brought about by selective breeding and genetics.

4. Students **elaborate** on their understanding by examining a range of scientific case studies showcasing different solutions WA agriculture is using to address the wicked problems:
   - Genetic modification (GM)
   - Selective breeding for worm resistance – using ASBVs
   - Cereal grain options
   - A2 milk production v normal milk
   - Biosecurity control of invasive and feral species
   - Future foods such as laboratory grown meat

5. Students **evaluate** their understanding of the key learning outcomes.

Educational process	Teaching and learning focus	Resources
Engage Engage students and elicit prior knowledge	**Module 1: Wicked problems and who is trying to solve them? (1 hour)** Students: • engage in discussion and research key issues facing WA agriculture • be introduced to key people (and careers) working in the field of agricultural research and innovation	PowerPoint presentation: • 1.0.1 What are the big issues in WA? Video: • 1.0.2 Caring about wicked problems in WA agriculture Student worksheets: • 1.1 Wicked problems facing WA agriculture
Explore Provide hands-on experience of the phenomenon, develop scientific explanations for observations and represent developing conceptual understanding	**Module 2: Exploring inheritance patterns (3 hours)** Teachers choose from practical, inquiry-based investigations designed to examine a range of inheritance patterns relevant to primary production: • Albino barley • Genetic modification: canola • Cross pollination of wheat varieties	Student worksheets: • 2.1.1 Albino barley – genetics or environment? • 2.1.2 Albino barley genetics or environment? (second hand data analysis) • 2.2.1 Genetically modified (GM) canola • 2.2.2 Genetically modified (GM) canola (second hand data analysis) • 2.3 1 Crossing wheat varieties • 2.3.2 Crossing wheat varieties (second hand data analysis) • 2.4 Group investigation framework
Explain Develop scientific explanations for observations and represent developing conceptual understanding. Consider current scientific explanations	**Module 3: Selective breeding and agriculture (1 hour)** Students explain: • the basic principles of how variation within agricultural plants and animals is brought about by selective breeding and genetics	PowerPoint presentation: • 3.0 An introduction to selective breeding and genetics Student worksheets: • 3.1 Selective breeding and genetics

Elaborate Extend understanding to new contexts or make connections to additional concepts through student-planned investigation	**Module 4: Case studies – applications of selective breeding and biotechnology to food and fibre production (6 hours)** Students elaborate on their understanding by examining a range of scientific case study activities that showcase how the wicked problems of climate change, food security and disease control are being addressed by WA primary producers: • Genetic modification of crops • Biosecurity – control of invasive and feral species • Aquaculture • A2 milk production v normal milk • Cereal grain technologies • Selective breeding of sheep – using ASBVs	Student worksheets: • 4.1 Case study 1: Genetically Modified (GM) crops • 4.2 Case study 2: Biosecurity – control of invasive and feral species • 4.3 Case study 3: Aquaculture • 4.4 Case study 4: A2 milk production • 4.5 Case study 5: Cereal grain crop technologies • 4.6 Case study 6: Selective breeding of sheep - using ASBVs
Evaluate Students demonstrate their understanding and reflect on their learning journey, and teachers collect evidence about the achievement of outcomes	**Module 5: What have I learnt? (1 hour)** This module focuses on students reviewing key concepts from this learning sequence. It consists of two separate activities. In the first activity students are engaged in a gallery walk of images used throughout the resource, and then use key terminology to create a concept map. This concept map is then compared with the first concept map produced in Module 1. This strategy illustrates to students whether they have built on their previous knowledge through engagement with the resources. In the second activity student reflect on their learning by using the process of 'Futuring'. Futuring involves thinking systematically about the future, drawing on scientific data, analysing trends, imagining scenarios (both plausible and unlikely) and thinking creatively. Students then showcase their ideas in the form of an expo.	Student worksheets: • 5.1 Gallery walk and concept map 2: WA primary producers – solving the big issues • 5.2 Futuring – Imagining the future for Western Australia

Prior knowledge

From studying Year 10 Science (biology) students it is assumed that students already have a basic understanding of how:

- the transmission of heritable characteristics from one generation to the next involves DNA and genes
- the theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence.

Learning resources and sequence (12 hours)

Module 1: Wicked problems and who is trying to solve them? (1 hour)

ENGAGE → EXPLORE → EXPLAIN → ELABORATE → EVALUATE

Learning intentions

Students will be able to:

- understand that there are big issues such as climate change, food security and biosecurity facing WA
- describe why these big issues are often called 'wicked problems'
- understand that wicked problems have ten key common properties
- develop research skills in examining careers associated with solving wicked problems

Resources

PowerPoint presentation:

- 1.0.1 What are the big issues in WA?

Video:

- 1.0.2. Caring about wicked problems in WA agriculture

Student worksheets:

- 1.1 The wicked problems facing Western Australian agriculture

Suggested instructions for activities

1. Begin the lesson with a short class discussion/brainstorm on the topic 'What are the big issues facing agricultural production in WA?' (PowerPoint 1.0 slide 2)
2. Form students into small groups and ask them to try to rank the issues in order of importance
3. Introduce the concept of the wicked problem – issues so complex that it is hard to grasp what the problem is or how to tackle them (PowerPoint 1.0 slide 3)
4. Have students focus on the PowerPoint 1.0 Image 1.0.1 which shows 10 characteristics of wicked problems. In small groups have students construct their own definition of a wicked problem. Allow time for students to share their definitions with other groups
5. Show students video 1.0.2 Caring about wicked problems in WA agriculture (PowerPoint slide 4). This video highlights the careers and contribution of key scientists working in agriculture in WA
6. Distribute Student worksheet 1.1. Allow students time to read the background information on wicked problems facing WA agriculture

7. Give students the option of learning more about wicked problems by following the link: [Wicked problems: Problems worth solving](#) (PowerPoint 1.0 slide 5)
8. Display PowerPoint slide 6 showing a map of rainfall trends in May-October during the periods 2000-2018 and 1910-1999. Encourage students to examine the map in their small groups and try to draw conclusions about trends occurring with the WA climate. Some students may need guidance on how to interpret the map
9. Have students describe what implications the reduction in rainfall might have for agricultural food production in WA
10. Display PowerPoint 1.0 slide 7 and discuss the FAO definition of food security
11. Allow students time to discuss the question 'Do you think we have food security in Australia and WA?'
12. Allow time for students to verify their ideas by following the links: [Analysis of Australia's food security and the COVID-19 pandemic](#) and [Food Security Plan For Western Australia](#)
13. Display PowerPoint 1.0 slides 8 – 10 on biosecurity. Ask students in small groups to list as many biosecurity threats as they can think of to WA's agricultural industries and share their list with other groups
14. Conclude this part of the lesson by having students examine Image 1.0.6 of feral pigs around a waterhole. Ask students to list as many biosecurity threats as possible to WA agriculture that they can think of. Ask students to ponder the question of why feral pigs that are descended from animals bred for food are considered a biosecurity threat
15. Direct students to the activity on Student worksheet 1.1. For students who are unfamiliar with concept mapping, the short video [How to make a concept map](#) is useful. Explain to students that their concept map will be needed at the end of the sequence of lessons as an aid to evaluating their learning

Module 2: Exploring inheritance patterns   (3 hours)

ENGAGE ➡ **EXPLORE** ➡ EXPLAIN ➡ ELABORATE ➡ EVALUATE

Learning intentions

In this module students are challenged to design and conduct a science investigation into selective breeding and genetics. Teachers may choose to conduct one of the three investigations or allow different groups of students to work on more than one concurrently. The investigations allow students to collaboratively demonstrate their understanding of the WA Curriculum Science inquiry skills content descriptors. Teachers will need to be flexible and tailor the investigation to suit the ability level of their students and the amount of time and resources available.

Through this process students will be able to:
- Formulate questions or hypotheses that can be investigated scientifically (ACSIS198)
- Plan, select and use appropriate investigation types to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)
- Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS200)
- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS203)
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204)
- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS205)
- Critically analyse the validity of information in primary and secondary sources, and evaluate the approaches used to solve problems (ACSIS206)
- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)

Resources and equipment

Student worksheets:

- 2.1.1 Albino barley – genetics or environment?
- 2.1.2 Albino barley genetics or environment? (second hand data analysis)
- 2.2.1 Genetically modified (GM) canola
- 2.2.2 Genetically modified (GM) canola (second hand data analysis)
- 2.3 1 Crossing wheat varieties
- 2.3.2 Crossing wheat varieties (second hand data analysis)
- 2.4 Group investigation framework

Notes and instructions for teachers and laboratory staff

Background information, pre-lab questions, a list of materials and equipment, as well as procedural instructions are provided within each of the student investigations. Teachers will need to choose the investigation(s) most suited to their student interests and abilities. Each investigation is intended to take approximately three hours of class time and is also accompanied by a second hand data activity designed to build data analysis and numeracy skills.

Student worksheet 2.4 is designed to assist students to go through the necessary steps of an investigation. Teachers may choose not to use this resource if they consider that their students do not require this level of scaffolding.

A typical three lesson sequence might be:

Lesson 1 – Planning and setting up the experimental procedure

Lesson 2 – Conducting the experiment, collecting and analysing the experimental data

Lesson 3 – Evaluating and communicating the results of the experiment

Student investigation 2.1: Albino barley - genetics or environment?

- Genetically selected barley seeds can be obtained from various suppliers of biological materials for schools

Student investigation 2.2: Genetically modified (GM) canola

- Both non-GM canola and GM canola (glyphosate tolerant) can be purchased from various agricultural seed suppliers

Student investigation 2.3: Crossing wheat varieties

- Two varieties of wheat are required. These can be sourced from the Department of Primary Industries and Regional Development (DPIRD), alternatively InterGrain can be contacted
- Ideally the two varieties need to differ (height, plant type, maturity etc.) so students can visualise what the progeny might look like
- Wheat varieties will need to be sown two months prior to the practical
- A PDF of instructions and tips for growing wheat at school can downloaded from the GRDC education resource Grain Facts for Schools: Grow Great Grains
- An excellent video explaining wheat anatomy and the steps for cross pollinating two wheat varieties is available at Wheat crossing protocol. Although some minor differences occur compared with the InterGrain steps, essentially the process is the same

Module 3: Selective breeding and agriculture   (1 hour)

ENGAGE → EXPLORE → **EXPLAIN** → ELABORATE → EVALUATE

Learning intentions

In this module students explore the genetic science behind the process of selective breeding to produce varieties of plants and animals for food and fibre. Through this process they will be:

- investigating changes caused by natural selection in a particular population as a result of a specified selection pressure such as artificial selection in breeding for desired characteristics
- describing biodiversity as a function of evolution

Additionally, students will be given the opportunity to explain how:

- advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE192)
- people use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE194)

Resources and equipment

PowerPoint presentation:

- 3.0 An introduction to selective breeding and genetics

Student worksheets:

- 3.1 Selective breeding and genetics

Suggested instructions for activities

1. Recap with students why continuous technological advancements in food production methods are needed to meet future food demands. Introduce the idea that since the beginnings of the Neolithic revolution 12 000 years ago humans have been altering the genetics of animals and plants by selective breeding from the biodiversity that naturally exists in a population (PowerPoint 3.0 slide 2)
2. Discuss the sophisticated food and agricultural systems of Aboriginal and Torres Strait Islander peoples as an example of agricultural practices selectively producing particular phenotypes (eg fire resistant species) (PowerPoint 3.0 slide 3)
3. Remind students of the important contributions of Charles Darwin and Gregor Mendel in influencing our current understanding of the genetics of selective breeding of plants and animals for food and fibre production (PowerPoint 3.0 slides 4 and 5). Links are provided on PowerPoint 3.0 slides 4 and 5 for students who wish to learn more
4. Pose the question to students of whether the food we eat today (such as wheat to make bread) is the same as it was thousands of years ago. Illustrate that modern varieties of animals and plants differ considerably from their original forms due to selective breeding – use emmer wheat as an example (PowerPoint 3.0 slide 6)
5. Ask students to try to define selective breeding – compare their answers with the definition on PowerPoint 3.0 slide 7
6. Watch the video Selective breeding on PowerPoint 3.0 slide 8
7. Hand out Student worksheet 3.1 and read through the background information on selective breeding and genetics with students. Allow students time to explore the links on the worksheet to learn more about the fundamentals of selective breeding

8. Direct students to activity 1, a simulation activity where students selectively breed pigeons to produce varieties of pigeons with specific characteristics: Pigeonetics
9. Begin activity 2 by explaining to students that modern selective breeding methods are now far more based on research and data than the methods used by our ancestors. These include a thorough knowledge of the biology and the genetics (the science of genomics) of the breeds and varieties being crossed to produce todays selectively bred hybrids
10. Allow students time to follow the links to find out more about how modern selective breeding technologies are helping address the big issues
11. Students use the information they have discovered to create an illustrated flowchart of how a breed of cattle that produces lower greenhouse gas emissions could be selectively bred by a WA primary producer
12. Introduce activity 3 which is a small group discussion examining the positives and negatives of selective breeding. Allow time for students to discuss this question and fill out the PMI chart provided
13. Finish the lesson with activity 4, an exploration of careers related to selective breeding. Links are provided on the worksheet
14. If time is available, encourage interested students to do extension activity 5, which challenges students to hypothesise and design an experiment about the intriguing question of why some chicken eggshells are white and others are brown. Even though students will probably not be able to physically test their hypothesis, they can follow the links on the worksheet to explain what the question has to do with selective breeding and genetics

Module 4: Case studies – applications of selective breeding and biotechnology to food and fibre production (6 hours)

ENGAGE → EXPLORE → EXPLAIN → **ELABORATE** → EVALUATE

Learning intentions

In this module students elaborate on their understanding of selective breeding and genetics by examining a range of scientific case study activities. The case studies have been designed to showcase how a variety of solutions are being used by WA primary producers to address the wicked problems of climate change, food security and biosecurity:

- Genetic modification (GM)
- Biosecurity control of feral and invasive species
- Aquaculture
- A2 milk production v normal milk
- Cereal grain crop technologies (including selective breeding, GM, genome editing, marker-assisted breeding)
- Selective breeding of sheep – using ASBVs

Resources and equipment

Computer/internet connection
Student worksheets:

- 4.1 Case study 1: Genetically Modified (GM) crops
- 4.2 Case study 2: Biosecurity – control of invasive and feral species
- 4.3 Case study 3: Aquaculture
- 4.4 Case study 4: A2 milk production
- 4.5 Case study 5: Cereal grain crop technologies
- 4.6 Case study 6: Selective breeding of sheep - using ASBVs

Instructions for suggested activities

Each of the case studies is designed to be done as an independent, self-guided exploration by students. Individual case studies vary in length and students will require access to computers and the internet.

Each case study is structured in a similar manner:

1. Background information on the particular topic is presented to students – students create notes of key ideas
2. A question or problem is presented to provoke thought
3. The science behind the technology is explored and explained. Where appropriate, second-hand data is presented for analysis
4. Where appropriate, students are challenged to consider ethical or moral questions associated with the solution
5. Where appropriate, students are given the opportunity to explore relevant, related careers

Recommended time required

Case study 1: Genetically modified (GM) crops (60 minutes)

Case study 2: Biosecurity – control of invasive and feral species (90 minutes)

Case study 3: Aquaculture (30 minutes)

Case study 4: A2 milk production (30 minutes)

Case study 5: Cereal grain crop technologies (90 minutes)

Case study 6: Selective breeding of sheep – using ASBVs (60 minutes)

(Note for teachers: Individual case studies may contain links to documents or articles that require a relatively high literacy level and therefore may require teacher scaffolding (eg Case study 3: Aquaculture: 'CSIRO – Genetics unravels the complexities of commercial prawn breeding'; 'Aquaculture Plan').

Module 5: What have I learnt? (1 hour)

ENGAGE → EXPLORE → EXPLAIN → ELABORATE → EVALUATE

Learning intentions

This module focuses on students reviewing key concepts from this learning sequence.

Resources and equipment

Student worksheets:

- 5.1 Gallery walk and concept map 2: WA primary producers – solving the big issues
- 5.2 Futuring – Imagining the future for Western Australia

Instructions for suggested activities

This lesson is designed to be student centred and self-paced (although teacher direction will be required).

Student worksheet 5.1 is designed to engage student interest through a gallery walk of images related to the topic. Gallery walk is a cooperative learning strategy where students are asked to share and contribute to each other's ideas. Throughout this series of activities, numerous images have been used to engage student interest. Teachers need to either select images (or have students select images) that are likely to stimulate discussion on how primary producers are solving the big issues of climate change, food security and biosecurity facing WA agriculture.

Conduct a gallery walk around the room examining the selected images (two minutes per image). Encourage students to take notes of their ideas. After students have examined all of the images, form small groups and encourage discussion and exchange of ideas.

The second part of this activity involves a review of key terminology presented throughout the resource to create a concept map.

This concept map is then compared with the first concept map produced in Module 1. This strategy illustrates to students whether they have built on their previous knowledge through engagement with the resources.

In Student worksheet 5.2 students reflect on their learning by using the process of 'Futuring'.

Futuring typically involves thinking systematically about the future, drawing on scientific data, analysing trends, imagining scenarios (both plausible and unlikely) and thinking creatively.

In small groups encourage students to discuss what they think their life will be like in WA in the future. Ask them to imagine what it will be like in 5 years, 10 years and 20 years.

Have students create a story, stop-motion video, a stand-alone PowerPoint presentation or a poster on how well they imagine WA will have coped with one of the wicked problems of climate change, food security or biosecurity.

Organise for students to present their ideas to other members of the class in the form of an expo.

Acknowledgements
References

Wicked Problems: Problems Worth Solving (nd) 'Wicked Problems' available at: <https://www.wickedproblems.com/1_wicked_problems.php> accessed 17 August 2021

Australian Government Department of Agriculture, Water and the Environment (13 January 2021) 'Analysis of Australia's food security and the COVID-19 pandemic' available at: <https://www.agriculture.gov.au/abares/products/insights/australian-food-security-and-COVID-19> accessed 17 August 2021

Curtin University and Perth NRM (2019) 'Food Security Plan for Western Australia: Situation report to guide the strategic development of a food security plan for Western Australia' available at: <https://www.regenwa.com/wp-content/uploads/2019/09/WA-Food-Security-Plan-Situation-Report-Sept-2019.pdf> [PDF 2.0MB] accessed 17 August 2021

Lucidchart (1 June 2018) video 'How to Make a Concept Map' available at: <https://www.youtube.com/watch?app=desktop&v=8XGQGhli0I0> accessed 17 August 2021

InterGrain (nd) 'Source Seed' available at: <https://www.intergrain.com/source-seeds/> accessed 17 August 2021

Australian Government Grains Research and Development Corporation (1 January 2016) 'Tips, tricks and tactics for growing wheat in your school veggie garden' available at: <https://grdc.com.au/resources-and-publications/all-publications/publications/2016/01/grain-facts-for-schools-grow-great-grains> accessed 17 August 2021

World Exploria (9 April 2020) video 'Wheat Crossing Protocol' available at: <https://www.youtube.com/watch?app=desktop&v=IVTjSTAc76M> accessed 17 August 2021

FuseSchool – Global Education (11 January 2017) video 'Selective Breeding | Evolution | Biologyl | FuseSchool' available at: <https://www.youtube.com/watch?app=desktop&v=fHS-OY9XDZc> accessed 17 August 2021

Genetics Science Learning Center (nd) 'Pigeonetics' available at: <https://learn.genetics.utah.edu/content/pigeons/pigeonetics/> accessed 17 August 2021

Suggested answers to student worksheets
WA primary producers – solving the big issues
Student investigation 2.1.1: Genetics or environment – albino barley
Pre-lab questions

1. Define the following key terms:

Term	Definition
allele	An alternative form of a gene
dominant trait	In genetics dominant describes a trait that is expressed in an organism's phenotype, masking the effect of the recessive allele
genotype	The genotype identifies the alleles related to a single trait (eg Aa), or to a number of traits (eg Aa Bb cc)
heterozygous	Of, or pertaining to, an individual (or a condition in a cell or an organism) containing two different alleles for a particular trait
phenotype	The phenotype describes the physical or physiological features of an organism and is the consequence of the expression of the genotypes
gamete	A gamete is the mature reproductive or sex cell that contains a haploid number of chromosomes (ie 50% of the genetic material or only one set of dissimilar chromosomes) and is capable of fusing with another haploid reproductive cell to form a diploid zygote
mutation	Permanent, heritable change in the nucleotide sequence or the process by which such a change occurs in a gene or in a chromosome

Source: Biology Online (© 2020 – 2021) available at:
<https://www.biologyonline.com/dictionary> accessed 25 August 2021

2. Use the punnet square below to show the possible genotypes and phenotypes if two hybrid barley plants are crossed (mated)

Symbols used for alleles: Green - **A**   Albino - **a**

Genotype of parent plants in the cross: **Aa** x **Aa**

Genotype of **gametes** each parent produced: Both **A** or **a**

Punnet Square showing possible offspring genotypes:

	Parent 1	
	A	**a**
A	**AA**	**Aa**
a	**Aa**	**aa**

(Parent 2 labels the left column)

3. From your Punnet Square, determine the ratio of offspring genotypes:

   1**AA**   :   2**Aa**   :   1**aa**

4. Of the possible offspring, determine the likely percentage of plants that are:

   Green phenotype: 75%

   Albino phenotype: 25%

5. Read over the method for this experiment. Based on this information, suggest possible:

   a)   independent variables: chlorophyll present/absent OR presence of light/dark

   b)   dependent variables: growth of barley, presence/absence of chlorophyll

   c)   controlled variables: temperature, water availability, gas concentrations

Student investigation 2.1.2: Genetics or environment – albino barley

Second hand data analysis

The following table shows the results of an investigation performed by a Year 10 Science class

Group	'Light' treatment			'Dark' treatment		
	Number of green seedlings	Number of albino seedlings	Albino seedlings (%)	Number of green seedlings	Number of albino seedlings	Albino seedlings (%)
1	9	3	25.0	0	12	100.0
2	8	4	33.3	1	11	91.6
3	9	3	25.0	0	12	100.0
4	10	2	16.7	0	12	100.0
5	7	5	41.6	0	12	100.0
6	9	3	25.0	0	12	100.0
7	11	1	8.3	1	11	91.6
8	9	3	25.0	2	10	83,3
9	10	2	16.7	1	11	91.6
10	9	3	25.0	0	12	100
Total	91	29	24.2	5	115	95.8
	Ratio of Green: Albino: 3:1			Ratio of Green: Albino: 1: 23		

1. Calculate the missing totals, percentages and ratios in the table (see above)

2. Plot the **percentage total** of green and albino seedlings for both the light and dark treatments on separate graph paper using an appropriate graphing format
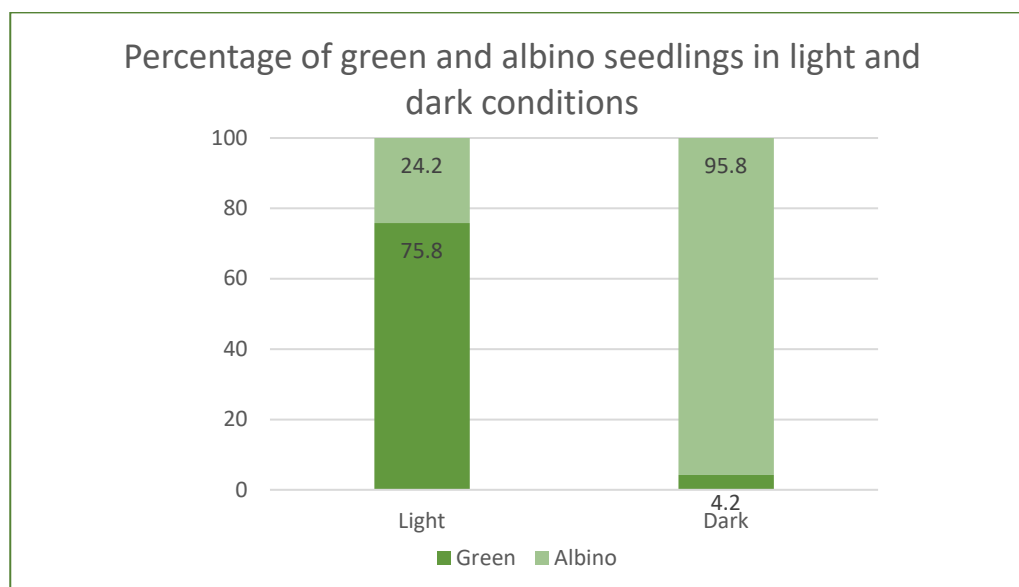
3. Suggest an appropriate **hypothesis** for this investigation.

    A variety of hypotheses are possible. A suitable hypothesis would be 'Both genetics and environment influence the development of chlorophyll in barley'

4. Identify at least one **controlled variable** in this investigation.
    Variables such as the amount of water and the environmental temperature would need to be controlled.

5. Suggest a reason why the data for each group is not exactly the same

    The data varies between each group due to the inherent natural variability within the seedlings as well as the random assortment that occurs during meiosis and fertilisation

6. What conclusions can you make about the influences of genetics and environment on the occurrence of the albino phenotype in barley?

    The data indicates that both genetics and environment influence the production of chlorophyll in barley

Student investigation 2.2.1: Genetically modified (GM) canola

Pre-lab questions

1. Define the following key terms:

Term	Definition
gene	A gene is the fundamental, physical, and functional unit of heredity.
chromosome	A chromosome is a structure within the cell that bears the genetic material as a threadlike linear strand of DNA bonded to various proteins in the nucleus
genotype	The genotype identifies the alleles related to a single trait (eg Aa), or to a number of traits (eg Aa Bb cc)
phenotype	The phenotype describes the physical or physiological features of an organism and is the consequence of the expression of the genotypes
transgenic	A term that describes an organism containing genes from another organism put into its genome through recombinant DNA techniques
Recombinant DNA technology	Genetically-engineered DNA molecule formed by splicing fragments of DNA from a different source or from another part of the same source, and then introduced into the recipient (host) cell

Source: Biology Online (© 2020 – 2021) available at:
<https://www.biologyonline.com/dictionary> accessed 25 August 2021

2. What are some possible advantages and disadvantages of transgenic crops?

Possible advantages of GM	Possible disadvantages of GM
Less pesticide use	Allergic reactions in some people
Increased nutrients	Possible increased antibiotic resistance
Increased disease resistance	
Cheaper	

## Student investigation 2.2.2: Genetically modified (GM) canola

Second hand data analysis

The following table shows the results of an investigation on GM canola and non-GM canola over a ten-day period. Both the GM and non-GM canola were grown together with mixed grass seed and herbicide.

Day	GM canola + mixed grass seed + herbicide		Non-GM canola + mixed grass seed + herbicide	
	Average height of canola seedlings (mm)	Change in height (mm)	Average height of canola seedlings (mm)	Change in height (mm)
1	1	--	1	--
2	3	2	3	2
3	5	2	5	2
4	7	2	6	1
5	9	2	6	0
6	12	3	7	1
7	14	2	8	1
8	17	3	8	0
9	19	2	9	1
10	21	2	9	0

1. Calculate the missing changes in height in the table (see above)

2. Plot the changes in height of both the GM and non-GM canola treatments on graph paper using an appropriate graphing format

Change in height of GM and Non-GM canola over time
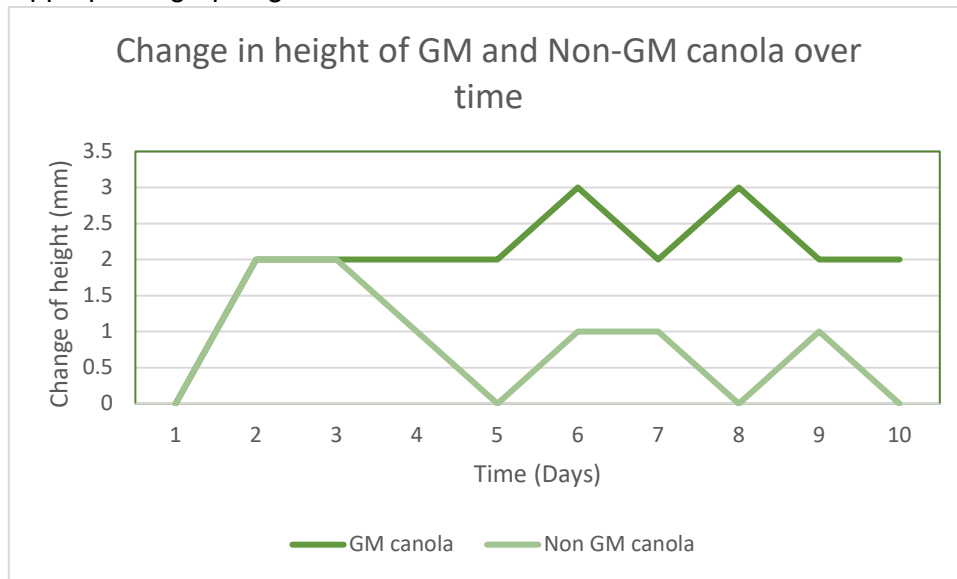
3. Suggest an appropriate **hypothesis** for this investigation.
A number of different hypotheses are possible. A suitable hypothesis would be:
'GM canola will grow more effectively than non-GM canola in the presence of weeds and herbicide'.

4. Identify the **independent variable** in this investigation.
The independent variable in this investigation is the use of either GM or non-GM canola.

5. What conclusions can you make about the effectiveness of GM canola compared with non-GM canola?

The data indicates that GM canola is more effective than non-GM canola at growing with weeds (mixed grass seed) and herbicide

Student investigation 2.3.1: Crossing wheat varieties

Pre-lab questions

1. Define the following key terms:

Term	Definition
progeny	Offspring, descendants
F1 hybrid	First generation hybrid. In reproductive biology, a hybrid is an offspring produced from a cross between parents of different species or sub-species
genotype	The genotype identifies the alleles related to a single trait (eg Aa), or to a number of traits (eg Aa Bb cc).
phenotype	The phenotype describes the physical or physiological features of an organism and is the consequence of the expression of the genotypes
dominant	In genetics dominant describes an allele that is expressed in an organism's phenotype, masking the effect of the recessive allele
recessive	In genetics a gene (or allele) whose phenotypic expression is masked by a dominant gene (or allele)
heterozygous	Of, or pertaining to an individual (or a condition in a cell or an organism) containing two different alleles for a particular trait
genetic improvement	When a desirable phenotype is produced by alteration of the genotype
self-pollination	A type of pollination in which the pollen from the anther of the flower is transferred to the stigma of the same flower
cross	An organism that is the offspring of genetically dissimilar parents or stock
trait	Characteristics or attributes of an organism that are expressed by genes and/or influenced by the environment
gamete	A gamete is the mature reproductive or sex cell that contains a haploid number of chromosomes (ie 50% of the genetic material or only one set of dissimilar chromosomes) and is capable of fusing with another haploid reproductive cell to form a diploid zygote

Source: Biology Online (© 2020 – 2021) available at:
<https://www.biologyonline.com/dictionary> accessed 25 August 2021

1. Wheat breeders are looking for certain traits or features in a plant. Plants inherit traits from both of their parent plants. These traits can be dominant or recessive. Use the punnet square below to show the possible genotypes and phenotypes if two wheat plants heterozygous for the phenotype of stem height (**Tt**) are crossed (mated).

Symbols used for alleles: Tall stem - **T**   Short stem - **t**

Genotype of parent plants in the cross: **Tt**   X   **Tt**

Genotype of **gametes** each parent produced: Both gametes are either **T** or **t**

Punnet Square showing possible offspring genotypes:

		Parent 1	
		T	**t**
Parent 2	**T**	**TT**	**Tt**
	t	**Tt**	**tt**

2. From your Punnet Square, determine the ratio of offspring genotypes:

1**TT**   :   2**Tt**   :   1**tt**

3. Of the possible offspring, determine the likely percentage of plants that are:

Tall stem phenotype: 75%

Short stem phenotype: 25%

Student investigation 2.3.2: Crossing wheat varieties

Second hand data analysis – a dihybrid cross in wheat

Phenotypes	Number of wheat plants
Tall, drought tolerant	895
Dwarf, drought tolerant	320
Tall, non-drought tolerant	280
Dwarf, non-drought tolerant	105

2.   Calculate the approximate **percentage** of each of the four different phenotypes

Tall, drought tolerant: 895/1600*100 = 56%

Dwarf, drought tolerant: 320/1600*100 = 20%

Tall, non-drought tolerant: 280/1600*100 = 17.5%

Dwarf, non-drought tolerant: 105/1600*100 = 6.5%

3.   Express these percentages as a **ratio**

Approximately 9:3:3:1

4.   Is this ratio close to what you would expect from this type of cross? Explain your answer.

9:3:3:1 is the expected ratio from a dihybrid cross

Student worksheet 3.1: Selective breeding and genetics

Student worksheet 3.1: Selective breeding and genetics

Activity 2: Selective breeding for lower GHG emissions

A generalised flowchart for selective breeding is available at: BBC Bitesize: Variation - Selective breeding

Activity 3: Examining the pros and cons of selective breeding

Some suggested positives and minuses are provided below

Positive	**M**inus
Selective breeding may help alleviate wicked problems such as climate change and food security Selective breeding may allow for increased profits New and useful varieties of crops and livestock are produced Limited safety issues	Loss of biodiversity Limited control over genetic mutations Animal welfare issues Increased environmental risk

Extension activity 5: Food for thought – why are some chicken eggshells white and others are brown?

A variety of different hypotheses are possible.

An example hypothesis might be: 'Egg shell colour is dependent on a chicken's diet'

A suitable experimental procedure would involve feeding the same breed of chicken a variety of different diets to see whether different coloured eggs were produced.

Chicken egg colours are dependent on the breed of chicken. For example, predominantly brown chickens such as Plymouth Rocks and Rhode Island Reds produce predominantly brown eggs, whereas white leghorn chickens produce predominantly white eggs. The different breeds of chickens are produced by the process of selective breeding.

Student worksheet 4.1: Case study 1: Genetically modified (GM) crops

Activity 1: GM research

An illustrated flowchart of the 'gene gun' approach to creating a transgenic plant is available at:
Learn Genetics: Genetically modified foods

Activity 3: Making your mind up about GM use in WA agriculture

Some suggested positives and minuses of GM are provided below

Positive	Minus
Less pesticide use	Allergic reactions in some people
Increased nutrients	Possible increased antibiotic resistance
Increased disease resistance	Cross contamination of non-GM crops
Cheaper	

Student worksheet 4.2: Case study 2: Biosecurity – control of invasive and feral species

Activity 1: Biosecurity and invasive species in Western Australia

Generalised invasion curve phase	Key ideas
Prevention	The most appropriate and cost-effective course of action in this phase is to invest in preparedness and surveillance, as well as research into better understanding of a species behaviour
Eradication	Once an invasive species has entered our efforts are best directed towards eradicating it to prevent further spread. The benefits outweigh the costs
Containment	When an invasive species has gone beyond being able to be eradicated, support for containment of the problem is needed. Economic returns on containment are lower than eradication
Asset based protection	Once an invasive species becomes established and has gone beyond containment, the focus becomes protection of key assets such as farmland, industries recreational areas and natural ecosystems. Typically, the return on this investment is low

Activity 3: Rabbits in Australia
### Data analysis

1. Calculate the cost (in DSE) to a farmer area if a paddock stocked with 300 sheep already contains 10 rabbit warrens
   10 DSE

2. When production costs, grazing pressure (DSE) and the value of the product (wool) are taken into account, a single rabbit can cost an individual WA wool producer $1.85 in lost production each year. Calculate the estimated cost during a rabbit plague if there were an estimated 5 000 rabbits on the wool producer's property.
   5 000*1.85 = $9 250

A challenge – calculating the exponential growth of a rabbit population

1. Given this information, calculate the number of rabbits in the population for the 10 years after the release of the initial 24 rabbits and enter the data in the table below. The first three calculations have been done for you.

n	r_n
0	24
1	84
2	294
3	1,029
4	3,602
5	12,605
6	44,118
7	154,414
8	540,450
9	1,891,575
10	6,620,514

2. Plot the data as a line graph on separate graph paper

Exponential growth of a rabbit poulation after 1859
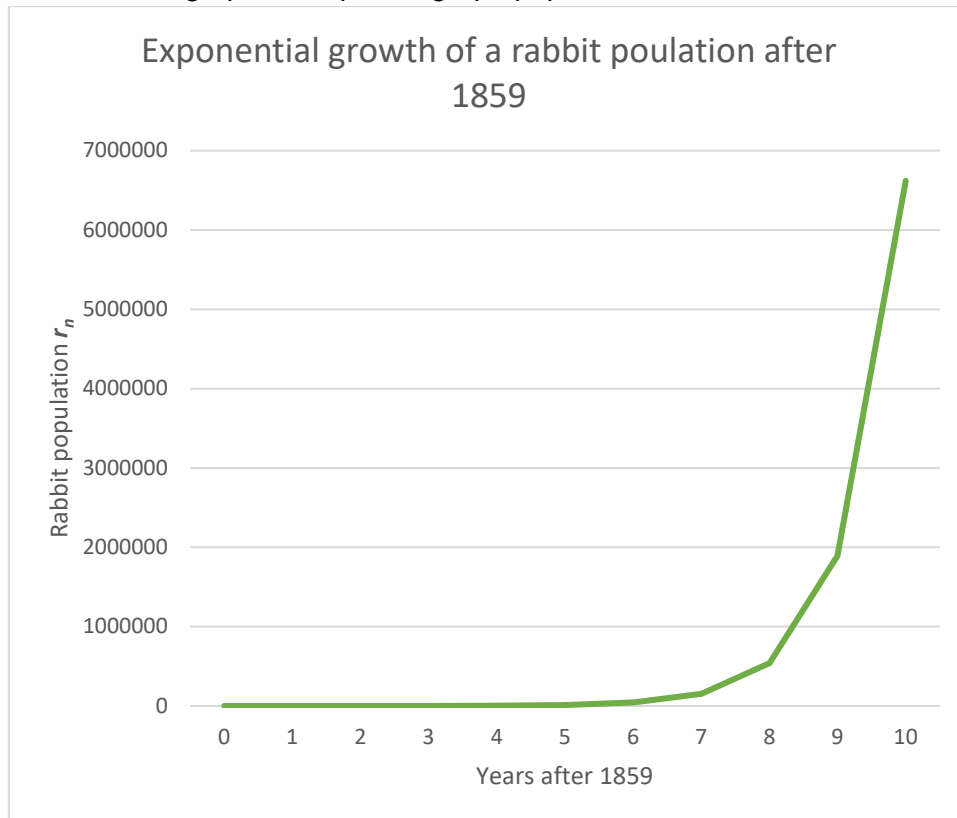
3. You probably had trouble trying to fit your data onto your graph paper. Can you think of any ways around this problem?
    This question may be quite difficult for many students to answer. Suggestions could include:
    -   plotting the data using a spreadsheet program or graphic calculator
    -   using semi-log graph paper

Rabbit plagues are relatively uncommon because this type of growth rate relies on various assumptions which, in reality, are unlikely to be sustained indefinitely.

4. What are some of the assumptions that have been made?

    Assumptions include:

    -   the population multiplication factor is constant at 3.5
    -   there are no predators or diseases
    -   individuals do not die
    -   the proportion of males and females each year remains at 50% males and 50% females

Biological control of rabbits

5. What is host-pathogen coevolution and how is it relevant to controlling an invasive species?

    Host-pathogen coevolution is an evolutionary relationship where the host and pathogen interact so intimately that the species affect each other's evolution in a reciprocal manner. When a pathogen such as the myxoma virus invades a host such as a rabbit, it has evaded the rabbit's defences. Coevolution is occurring if the rabbit evolves mechanisms to live without eliminating the virus. Decreased virulence of the virus has also evolved.

    Host pathogen coevolution may make biological control of an invasive species using a pathogen less effective.

Student worksheet 4.3: Case study 3: Aquaculture

Activity 1: An example of selective breeding in aquaculture - the black tiger prawn
Selectively bred features of the Australian black tiger prawn

-   Tastier
-   More productive – improved growth and survival rates, > 50% boost in yields

Understanding the genetics of selective breeding of prawns for aquaculture
Questions

1. Genetic diversity is the sum of the various alleles within a species or population

2. The maintenance of genetic diversity in selectively bred populations is important to maintain population health. It is important to maintain alleles in the population pool that may be valuable in resisting diseases, pests and other stresses. Maintaining diversity gives the population a buffer against change, providing the flexibility to adapt.

3. Using a genetic marker system was essential to be able to identify the prawn families that were producing the largest number of offspring for future breeding, whilst at the same time monitoring genetic diversity.

Activity 3: Making up your own mind - is aquaculture the solution to the wicked problem of food security?

Pros of aquaculture	Cons of aquaculture
Increased access to consistent food supply	Increased opportunity for spread of disease
Increased economic returns and employment opportunities	Loss of biodiversity, disruption of natural ecosystems
Reduced pressure on natural aquatic food chains	Often food for aquaculture species is farmed from other wild-harvested species
Reduction in the reliance on scarce wild-catch aquatic species	Environmental contamination from aquaculture wastes, pesticides and drugs
Increased long-term sustainability	Health concerns regarding the quality of aquaculture produced seafood

Some of the ways that the scientists are dealing with the issues faced by aquaculture include:

- Certification and labelling of aquaculture products to ensure consumers are able to make informed decisions
- Improved farm management practices
- Growth of seaweed near aquaculture pens to capture resource runoff
- Using building materials and methods with minimal environmental footprint

Student worksheet 4.4: Case study 4: A2 milk production

Activity 1: The science of producing A2 milk

1. A2 milk is cow's milk that contains only the A2 variant of beta-casein protein. Prior to domestication cows produced only the A2 beta casein protein and not the A1 version. A natural single-gene mutation occurred in Holsteins resulting in production of the A1 beta casein protein. Milks from Guernsey, Jersey, and Asian dairy herds contain mostly A2 beta casein. Milks from Holstein Friesian contain mostly A1 beta casein. The Holstein breed (the most common dairy cow breed in Australia) carries A1 and A2 forms. A2 milk is produced by the selective breeding of breeds of dairy herds with predominantly A2 protein.

(Source: California Dairy Research Foundation (9 February 2017) 'A2 milk facts' available at: <https://cdrf.org/a2-milk-facts/> accessed 4 July 2021)

Activity 2: The genetics of cross breeding to produce an A2 cow

2. What is the probability that the unborn calf produced in the mating is an A2 milk producing female? Set out your reasoning below – you will need to use at least one punnet square to justify your predictions:

Symbols used for alleles: A1 milk production – **A1**   A2 milk production – **A2**

Situation 1: If the Holstein cow is **A1A2**, then:

Genotype of parent plants in the cross: **A1A2** x **A2A2**

Genotype of **gametes** each parent produced: Holstein cow **A1** or **A2;** Jersey bull **A2**

Punnet Square showing possible offspring genotypes:

Parent 2	Parent 1		
		A2	**A2**
	A1	**A1A2**	**A1A2**
	A2	**A2A2**	**A2A2**

Of the possible offspring, the likely percentage that are female and A2 phenotype: 25%

Situation 2: If the Holstein cow is **A1A1**, then:

Genotype of parent plants in the cross: **A1A1** x **A2A2**

Genotype of **gametes** each parent produced: Holstein cow **A1**; Jersey bull **A2**

Punnet Square showing possible offspring genotypes:

		Parent 1	
		A2	**A2**
Parent 2	**A1**	**A1A2**	**A1A2**
	A1	**A1A2**	**A1A2**

Of the possible offspring, the likely percentage that are female and A2 phenotype: 0%

The overall probability of the offspring being an A2 milk producing female: 12.5%

3. Describe the role that **genomic testing** might play in the selective breeding of A2 milk producing cows

   Genomic testing would be useful to determine whether the Holstein cow selected carries the A2 allele. This would increase the probability of the offspring being an A2 milk producing female.

Student worksheet 4.5: Case study 5: Cereal grain crop technologies

Activity 1: Selective breeding of cereal grain crops

1. Which varieties would you choose to cross? Justify your choice

   A hard grain variety suitable for both bread and noodles such as Rockstar or Vixen would need to be crossed with a variety tolerant to weed control herbicides such as Chief CL Plus in order to combine both of these qualities in the progeny

2. What name would you give your new variety?

   (Student answers will vary)

3. Create a flowchart of the processes involved in selectively breeding the new variety

   A flowchart of selective breeding of a new cereal grain crop variety can be found at:

   GRDC – Science of crossing and crops (pages 8 – 10)

Activity 2: Genome editing

Summarise how genome editing technologies (such as CRISPR) might be used to assist the improvement of cereal grain crops and thus assist with solving agriculture's wicked problems

Who first developed the genome editing technology CRISPR? Scientists at UC Berkley	**What** processes are involved in a genome editing technology such as CRISPR? Modern genome editing technique involve using enzymes to cut DNA strands at a precise point in the sequence, creating a 'double stranded break' that is then repaired by the cell, leading to a change in the genome.	**When** were genome editing technologies such as CRISPR first developed? The CRISPR/Cas9 genome editing tool was first described in 2012 and 2013.
Where in agriculture do you see genome editing technologies such as CRISPR having the most impact? Genome editing could be tremendously useful in agriculture. It can be used to silence undesirable genes in crops, such as the genes responsible for browning in mushrooms, and to alter the behaviour of other genes, eg causing an increase in fruit size or yield, or stimulating the production of useful natural products.	**How** does genome editing technology differ from conventional GM? In your opinion, does it have the same ethical problems we usually associate with conventional GM? Unlike conventional GM using transgenics involving the insertion of whole DNA sequences into a genome, genome editing involves making precise changes to an organism's native DNA, effectively making small corrections to the DNA that was already there. Because genome editing does not produce transgenic organisms, there may be less ethical problems.	**Why** is genome editing considered to be a superior approach compared with conventional GM? Unlike transgenics, genome editing is much quicker and cheaper to perform and the technique itself is much more precise, increasing the success rate of new engineered crops

(Source: IDTechEX Research article: Dent. M (25 September 2020) 'Genome Editing Technologies Could Revolutionise Agriculture' available at: https://www.idtechex.com/en/research-article/genome-editing-technologies-could-revolutionise-agriculture/21714> accessed 9 September 2021)

Activity 4: Extension research activities

1. Research how both genomics and phenomics are being used to provide innovative solutions to world food security.

   One of the most popular uses of genomics in breeding is the prediction of breeding values, thus making selective breeding outcomes more predictable. Genomic selection reduces cycle time, increases the accuracy of estimated breeding values and improves selection accuracy.

   Developments in plant phenomics provides opportunity to dissect complex, quantitative traits when both genotype and phenotype can be assessed at a high level of detail.

   When an approach by food producers incorporating both genomics and phenomics is used, significant efficiencies in food production can be produced thus assisting food security.

2. What is **marker-assisted breeding?** How does this approach assist farmers?

'Marker-assisted breeding uses DNA markers associated with desirable traits to select a plant or animal for inclusion in a breeding program early in its development.

This approach dramatically reduces the time required to identify varieties or breeds which express the desired trait in a breeding program. The marker may be the sequence of the gene that determines the trait, but in most cases, it is a DNA sequence which is located very close to the gene of interest and is therefore always inherited with the trait. Desirable traits include characteristics such as disease resistance, salt tolerance and high yield.'

(Quotation source: CSIRO (22 January 2021) 'Marker assisted breeding' available at: <https://www.csiro.au/en/research/animals/breeding/marker-breeding> accessed 26 August 2021)

3. What is **precision agriculture**? Is it a likely answer to climate change and food security?

'Precision agriculture seeks to exert more control over a production system by recognising variation and managing different areas of land differently, according to a range of economic and environmental goals. To do this, the tools of Precision Agriculture are used to collect large amounts of data on crop or animal performance and the attributes of individual production areas (for example, fields, paddocks and blocks) at a high spatial resolution.'

(Quotation source: CSIRO (29 March 2021) 'Precision agriculture' available at: <https://www.csiro.au/en/research/plants/crops/farming-practices/precision-agriculture> accessed 26 August 2021)

Student worksheet 4.6: Case study 6: Selective breeding of sheep – using ASBVs

Activity 2 – Genetic selection using Australian Sheep Breeding Values (ASBV)

Using ASBVs is advantageous to Western Australian sheep breeders because ASBVs are a prediction of an animal's genetic merit for a particular trait. There are ASBVs for many different traits that impact the performance and profitability of sheep enterprises. These include:

- growth traits

- carcase and eating quality traits

- wool traits

- reproduction traits

- health traits.

They are an indication of how an animal's progeny will perform based on the genes they will pass on. ASBVs are comparable across flocks. ASBVs therefore allow sheep breeders to plan and predict the outcome of crossing their sheep more accurately.

(Source: Sheep Genetics (2020) 'ASBVs and indexes explained')

Activity 3: Using ASBVs to select for worm resistant sheep

Analysing research data on worm resistance

Based on the data, the DPIRD researchers' conclusion that the Rylington Merino flock is a highly resistant flock compared with flocks that have not been selectively bred for worm resistance is justified. Both sets of data presented in Images 4.2.4 and 4.2.5 show significant differences between the test and control flocks.

Acknowledgements
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