THE SCIENCE OF CROSSING AND CROPS

HOW MODERN SCIENCE IS HELPING PRODUCE MORE FOOD IN A CHANGING CLIMATE

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

A TEACHING UNIT FOR YEAR 11 SCIENCE STUDENTS

About the GRDC

The GRDC

The Grains Research and Development Corporation is a statutory authority established to plan and invest in research, development and extension (RD&E) for the Australian grains industry.

Its primary objective is to drive the discovery, development and delivery of world-class innovation to enhance the productivity, profitability and sustainability of Australian grain growers and benefit the industry and the wider community.

Its primary business activity is the allocation and management of investment in grains RD&E.

GRDC Vision

A profitable and sustainable Australian grains industry, valued by the wider community.

GRDC Mission

Create value by driving the discovery, development and delivery of world-class innovation in the Australian grains industry.

GRDC Values

- We are committed and passionate about the Australian grains industry.
- We value creativity and innovation.
- We build strong relationships and partnerships based on mutual trust and respect.
- We act ethically and with integrity.
- We are transparent and accountable to our stakeholders.

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Contents

1.0 Teaching the science of grains

The Grains Research and Development Corporation has invested in the development of a suite of user-friendly grain education resources and initiatives for students, teachers and families.

These resources have been developed with teacher and researcher input and have been designed following a comprehensive survey of more than 340 teachers throughout Australia.

In each of our curriculum-linked resources we have worked to incorporate a range of lesson plans which explore the latest science, technology, engineering, mathematics, nutrition, research and innovation in the Australian agricultural industry. You can use these resources as a unit or select components to complement your teaching plan.

Using an investigation and inquiry based approach students will touch, try, taste and even smell the science of the Australian grains industry. It provides an ideal and relevant teaching context to engage students in food production.

Specifically, resources are available to address the food and fibre curriculum descriptors in geography, science, home economics and agriculture.

We hope you have fun teaching with these resources. Please contact us for more information.

Kind regards
The GRDC Education Team

2.0 Learning outcomes and curriculum links

About the science of crossing and crops

Much has changed since the first grain plants arrived in Australia in 1788. The challenges of farming in Australia have driven scientists to adopt new and exciting technologies. Ongoing advances in plant breeding have allowed Australian scientists to deliver better varieties to grain farmers in a more efficient and effective manner.

Plant breeders are tasked with genetically improving plants so that crops possess traits that are more desirable. Conventional methods stem from ancient practices which allowed humans to domesticate plants suitable for farming. Scientific approaches to plant breeding began in the mid-19th century and since then plant breeding techniques have accelerated.

In the past, plants have been selected for desirable traits through trial and error and an assessment of phenotypes. The seeds of these plants were then harvested to sow future crops. Modern plant breeding has seen scientists looking for these desirable characteristics at a genetic level (genotype) with new technologies continually being developed to make this a precise and time efficient process. Adopting the practical processes of a plant scientist, this resource engages students in modern plant breeding techniques used within the grains industry.

Learning outcomes

Students gain an insight into how the ongoing advances in breeding have allowed Australian scientists to deliver better plant varieties to grain farmers. Adopting the practical methods of a plant scientist, this resource engages students in modern plant breeding techniques used within the grains industry. Students conduct a DNA extraction and try their hand at a genetic cross. This unit focuses on key words, activity and practical based exploration of genetics and highlights the influence of scientific understanding.

Curriculum focus

Students should be able to

- Communicate understanding of heritable characteristics.
- Complete practicals which reflect the modern practices in scientific research.
- Formulate a hypothesis which is reflective of comprehension of genetics and plant breeding.

Australian curriculum content descriptions

Heredity and the continuity of life

Science inquiry skills

Conduct investigations including the use of probabilities to predict inheritance patterns, real or virtual gel electrophoresis, and population simulations to predict population changes, safely, competently and methodically for the collection of valid and reliable data (ACSBL063).

Science as a human endeavour

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073).

Science understanding

DNA, genes and the continuity of life

Frequencies of genotypes and phenotypes of offspring can be predicted using probability models, including Punnett squares, and by taking into consideration patterns of inheritance, including the effects of dominant, autosomal and sex-linked alleles and multiple alleles, and polygenic inheritance (ACSBL085).

3.0 Teaching unit content and overview

This resource contains a range of curriculum-linked lesson plans which teachers can cut, paste, and utilise as they see fit. Our team work to develop resources which are interactive, fun and fit into your busy teaching schedule. The below table summarises the wide modes of engagement strategies including science experiments, exploring critical and lateral thinking and investigation. You can use some of these lesson plans or all. Whatever you do, we hope you have fun teaching your students about plant and grain science.

	4.0 Introduction	Introduce the topic of plant breeding to students, asking them what methods they are aware of. Discuss with students the reason behind plant breeding.
PAGE 9	**Brainstorm** Plant selection	Students are to list some of the challenges that arise in growing grains e.g. drought, soil salinity, low yield, disease. Ask them to think about the environment of the local area and with this is mind, list some characteristics that would be desirable if they were to farm grains in this area. Plant breeding – students are to look at the characteristics of each plant and circle those which are desirable.
PAGE 10	**Insight** Making baby plants	This insight provides an overview of conventional plant breeding methods.
PAGE 12	**5.0 Insight** Plant genetics	Students are to learn key words: alleles, dominant, recessive, genotype, phenotype, homozygous, heterozygous.
PAGE 15	**6.0 Practical** Check out their genetics!	This task asks students to be plant breeders. They are to firstly read the list of traits in a grain plant and identify those which are desirable. Students are then to follow the instructions to simulate cross breeding their plant variety with that of a friend. Provide students with paper, string and clips to create their strand of DNA. *Idea: Following this task, get the students to practise this by allowing students to create master plant phenotypes and cross with a plant of a friend e.g. poisonous spikes, eyes, Venus fly trap head. Ask them to draw an annotated diagram of both their grain crop offspring and their master plant offspring to display in the classroom.* Step 1: The squares could be pre-prepared by the teacher or prepared in class by the students. Step 2: This could be extended to include teaching about 'gametes'. Students could select a 'X' or 'Y' POLLEN (male) or 'X' OVULE. Attach the alleles to the POLLEN or OVULE using a piece of string or sticky tape. Step 3: Ask the students to repeat this twice with their peer so they each have their own plant to draw and annotate. Step 4: If your students are not familiar with punnet square and ratios, complete the 'Punnet squares and genotypic ratio' activity before carrying onto Step 4. **See appendix*

PAGE 18	**7.0 Activity** Punnet squares and genotypic ratios	An introduction to punnet squares, this lesson provides examples and tasks to engage students in their learning. It uses punnet squares for monohybrid crosses. Extension: Punnet squares used to explore crosses. **See appendix*
PAGE 22	**8.0 ACTIVITY** A tonne of varieties	This activity focuses on the relationship between plant breeder and grain grower. Students are to look at the available lentil varieties in Australia and plan a cross breed of two of these to create a new variety including completing tables to represent the cross and providing a short summary of its potential. **See appendix*
PAGE 24	**9.0 Research** Better grain for everyone	Engaging information literacy skills, this task focuses on international collaborations for enhancing scientific research and development. Students are to use key words and concepts in their search. Good sources of information include: **www.GRDC.com.au * www.cimmyt.org * www.planttreaty.org**
PAGE 25	**10.0 Activity** New challenges, new varieties	Engaging their reporting skills, students will investigate one of the grain and pulse crops grown in Australia. They will need access to the internet and guidance in research. Depending on current science media, the level of ease in finding information about a particular crop will differ but wheat, barley, canola and lentils are often easier. Suggested research portals include Grains Research & Development Corporation, ABC Rural, local universities and news websites. **In the 'Good Reads' section of this resource find articles on barley domestication and wild rice in Australia which would be good supporting resources for this task.*
PAGE 26	**11.0 Activity** Variety feature	Featuring a variety grown in Australia, this activity tasks students with investigating the parent plants of this new variety and identifying the desirable traits selected in each parent plant. Access to the internet and the Australian Grain Technology website is needed. Link: **http://www.agtbreeding.com.au/varieties/wheat**
PAGE 28	**12.0 Insight** DNA basic	Highlighting the work of Noble Peace Prize winning plant breeder Dr Norman Borlaug, students are reminded of the reasons behind plant breeding for food security. Additionally, students are provided with a summary of DNA, traits and simple DNA extraction leading in to the practical DNA extraction.
PAGE 30	**13.0 Practical** DNA extraction	This simple procedure will allow students to extract the DNA from wheat germ. Students will need a laboratory coat and glasses, wheat germ, detergent, meat tenderiser, baking soda, methylated spirits, measuring cylinder (min 100ml), plastic cup, pipette and a spoon to mix. Students must be provided with a well-ventilated area to conduct this experiment and supervision ensured. Students are to complete a brief scientific report, which could include materials, method, observation and discussion.

4.0 INSIGHT
Plant Selection

Australian farmers face many challenges when growing grains in Australia. The grain and pulse crops grown originate from other parts of the world and are not always well suited to our environments.

As a result, growing crops can be challenging and plant breeding is crucial to producing plentiful crops. Plant breeding allows scientists to create new varieties by selecting plants with different desirable traits and cross breeding them with each other in the hope that the offspring will express these traits.

Plant selection

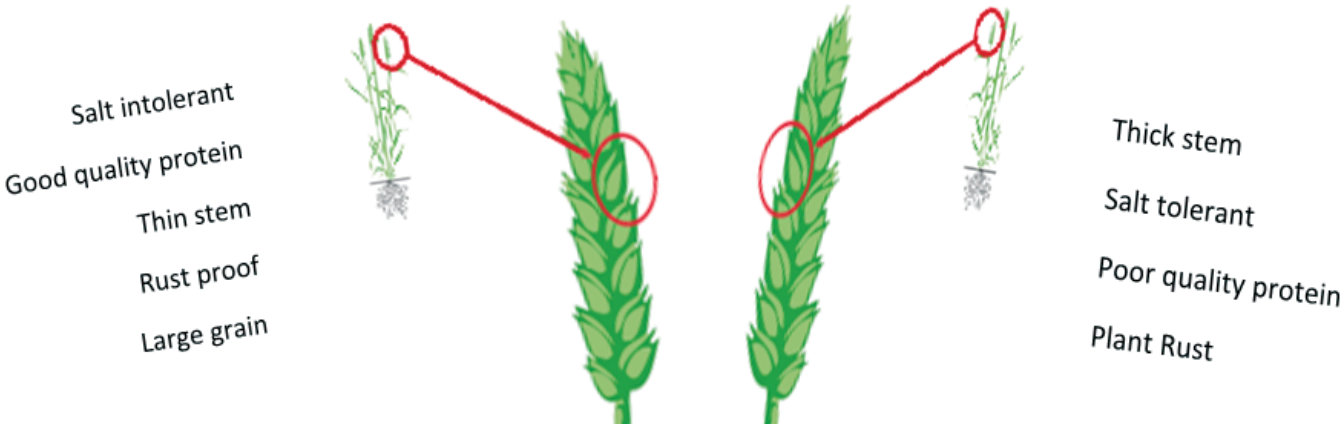
Although the crossing of plants has been occurring for centuries, contemporary advances in technology are helping to make this process more effective and efficient. Scientists can crossbreed plants by hand, through a trial process or even select characteristics at a genetic level.

Brainstorm

What are some of the challenges of growing a grain crop?

What characteristics would be desirable in a grain crop grown in your area of Australia?

Here are two varieties of barley with different characteristics. Circle the characteristic which you believe would create a better new variety.



Making baby plants: the plant breeding process

1. Select parent plant with desired characterisitcs.

2. Male pollen taken from one parent and transferred onto the female stigma of the other plant to fertilise.

3. Seed is collected from offspring plants and sown at trial sites.

4. More selections and eliminations are made using trial sites.

5. The best performing plants are tested for weight, protein quality, disease resistance, growth and performance.

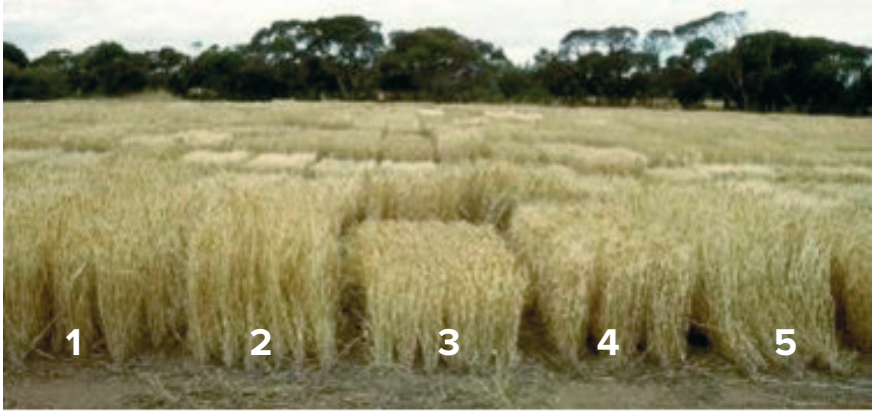
6. Successful plants or new varieties are replicated and their seeds collected to pass onto farmers.

Create your own baby crop plant!

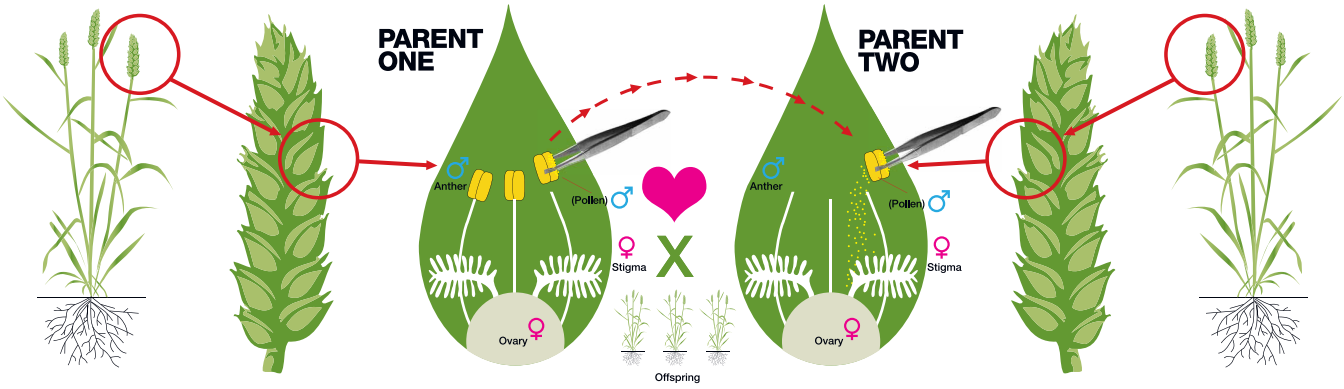
Here is a brief overview of how plant scientists transfer the genes of one wheat plant into another.

1. Select your parent plants

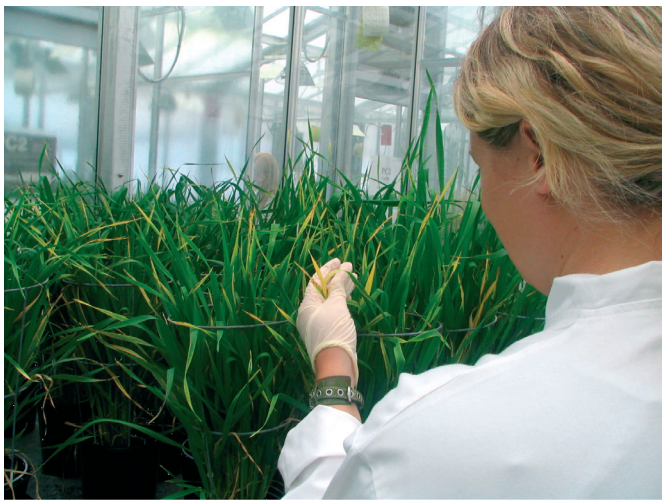
e.g. 1. Shallow roots 2. Tall stem 3. Dwarf 4. High yield 5. Susceptible to lodging (tendency for mature plants to blow over)



2. Make the cross



3. Pop a bag on their head to stop them cross breeding with anyone else...
Grow the plants in a glasshouse (love and water them!).



5.0 INSIGHT
Plant genetics

Breeding plants is about plant love and genetics.

Plant breeders are looking for certain traits or features in a plant. Plants inherit traits from their parent plants. These traits can be dominant or recessive.

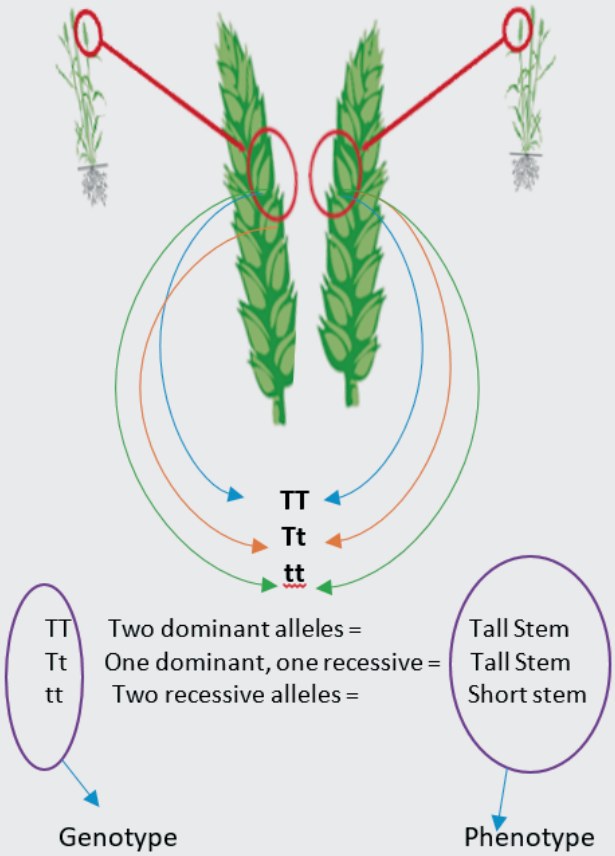
When breeders are looking at the traits, they are referring to a set of a plant's alleles. An allele is a different form of the same gene. For example, eye colour is determined by a gene and that gene could have alleles for blue, green or brown colouring. In the image shown, the tall stem is the dominant allele and the short stem is the recessive allele. Alleles are represented by a single letter and are passed onto offspring in different combinations.

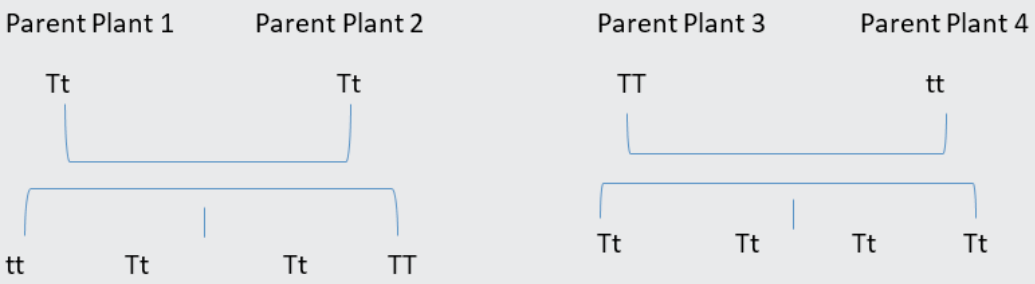
A dominant gene will be expressed if each of the alleles is dominant or if the combination is one dominant and one recessive allele. This is because a dominant gene will mask a recessive gene.

A recessive gene is expressed when no dominant alleles are present and there are two recessive alleles.

This set of alleles passed on is called a genotype and determines the expression of a particular characteristic or trait.

The 'phenotype' is the expression of the genotype e.g. physical appearance.





Homozygous dominant	Two dominant alleles	TT
Homozygous recessive	Two recessive alleles	tt
Heterozygous	One dominant allele and one recessive allele	Tt or tT

Write your understanding of the following key terms

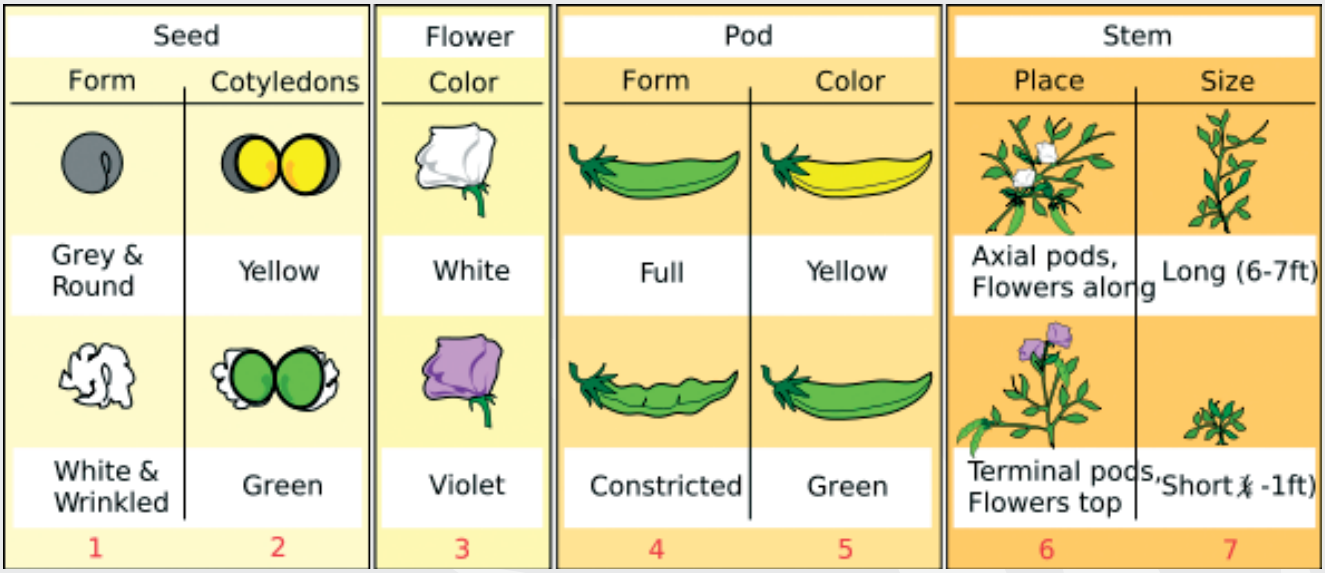
ALLELE	
DOMINANT	
RECESSIVE	
GENOTYPE	
PHENOTYPE	
HOMOZYGOUS RECESSIVE	
HETEROZYGOUS	
HOMOZYGOUS DOMINANT	

Gregor Mendel

During the 18th century, scientists had a better understanding of cell division and sexual reproduction thanks to the advancement of microscopes.

Scientists began to focus on how traits were transferred from parents to offspring. Gregor Mendel (1822 – 1884) was one of these scientists who experimented with crossbreeding to help him understand inheritance. Mendel discovered that offspring inherit traits from each parent, rather than traits which have been blended or mashed together.

In his pea plant experiments, Mendel recorded that the pea plant's flowers were either purple or white, the stem was either long or short, and the seed was either round or wrinkled. Mendel also noted that traits are inherited in certain ratios and patterns. This was the start to understanding breeding and later, to understanding genes.



Seven characteristics of pea plants which Mendel focused on in his research (Source: Wikimedia CC)

6.0 PRACTICAL
Check out their genetics!

TASK: You are a plant breeder. A group of grain growers have come to you with a list of traits they desire in their crops. Your job is to crossbreed a plant that expresses at least some of these desired traits.

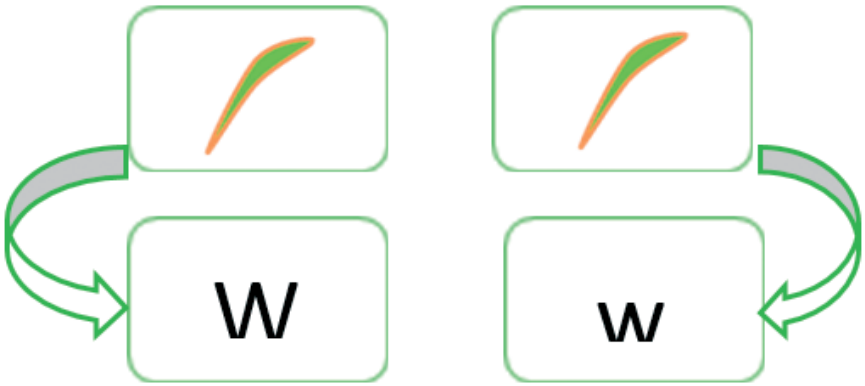
D = dominant R = recessive

	DESIRED TRAIT Read through the below descriptions and identify the phenotype that you believe is more desirable in a grain plant. Record this and proceed to 'Step one – creating alleles'.	**PHENOTYPE**		**GENE VARIATION – ALLELE**
WAXY	**Wax** Plants lose water through the cuticles on the surface of their leaves. This can lead to the plant becoming dehydrated. Plants that possess a waxy coating over their cuticles lose water at a slower evaporation rate. **Desired trait** _____	Waxy	**R**	**w**
		Non-waxy	**D**	**W**
CEREAL CYST NEMATODES	**Cereal Cyst Nematodes (CCN)** Cereal Cyst Nematodes are a significant pest across the globe including in Australia. This type of nematode specifically affects cereals by infecting, feeding and growing on them. CCN will cause the crop to become yellowed and stunt growth in the plant, with closer inspection of the roots revealing specie specific effects (e.g. wheat roots will be knotted). **Desired trait** _____	CCN resistant	**D**	**C**
		CCN non-resistant	**R**	**c**
BORON	**Boron** It is believed that a small amount of the element boron is important to the cell health of plants. If the plant receives too little boron it will suffer from boron deficiency and if it receives too much it will suffer from boron toxicity. Plants should be tolerant to boron to ensure they receive boron but are not affected by toxicity. **Desired trait** _____	Boron tolerant	**D**	**B**
		Boron intolerant	**R**	**b**
STOMATA	**Stomata** Stomata are openings on the surface of the leaf which allow for carbon dioxide to be absorbed. This unfortunately also leads to water being lost from the plant. Plants which grow in dry conditions, like much of Australia, usually have small stomata to minimise the loss of water. **Desired trait** _____	Large stomata	**D**	**S**
		Small stomata	**R**	**s**
QUALITY	**Protein** Dough functionality and suitability is dependent on the quality of grain protein. Strong protein quality in cereal grains results in better quality products. For instance, stronger protein quality results in stretchier bread dough. **Desired trait** _____	Strong protein quality	**D**	**P**
		Poor protein quality	**R**	**p**
HEIGHT	**Height** At the end of the growing period, the part of the plant that a farmer wants to harvest is the head as this is where the grain is. Consequently, when growing this grain, the head is where most of the energy and water needs to go. In earlier grain growing days of Australia, cereal grain plants had long stems which meant a lot of energy was going into the stem. **Desired trait** _____	Tall	**D**	**H**
		Dwarf	**R**	**h**

STEP ONE – CREATING ALLELES

1. Find a partner.
2. Cut out 12 identical squares.
3. Label two squares with the picture of leaves.

   On the reverse side of one of these squares write a '**W**' (allele for waxy leaf) and on the other write a '**w**' (allele for non-waxy leaf).
4. After completing the table below, repeat this exercise for all of the tabulated traits below.



	WAXINESS		CEREAL CYST NEMATODE		BORON	
PHENOTYPE	Waxy	Non-waxy	Resistant	Non resistant	Boron tolerant	Boron intolerant
ALLELE	W	w	C	c	B	b
GENOTYPE	WW or Ww	ww	_____	cc	_____	bb

	STOMATA		QUALITY		HEIGHT	
PHENOTYPE	Large Stomata	Small Stomata	Strong protein quality	Poor protein quality	Tall	Dwarf
ALLELE	S	S	P	p	H	h
GENOTYPE	SS or Ss	_____	_____	_____	_____	_____

STEP TWO – RANDOM SEGREGATION OF ALLELES

Alleles exist in pairs and separate in breeding. This process of separation is known as random segregation.

5. Lay all the cards of alleles out on the tables in pairs with the picture facing upup
6. Randomly select one card from each pair. For example, take one of the 'waxiness' cards, one of the 'CCN' cards and so on.

STEP THREE – FERTILISATION – ALLELES RANDOMLY UNITE

7. Cross breed your plants alleles with those of your partners plant!
8. Combine your alleles to find out what your plant will look like.

TRAIT	GENOTYPE	PHENOTYPE
WAXY		
CEREAL CYST NEMATODE		
BORON		
STOMATA		
QUALITY		
HEIGHT		

Draw and annotate your plant!

Comment on the value of this phenotype to a wheat farmer

7.0 ACTIVITY
Punnet squares and genotypic ratios

A punnet square is a table which can be used to understand the likelihood of a trait being passed onto offspring. Scientists can use a simple punnet square to predict the outcome of a particular cross or breeding experiment.

In partnership with this table, genotypic and phenotypic ratios can be used to describe the relative number of offspring with certain traits. Ratios can be calculated by counting the number of homozygous dominant, homozygous recessive and heterozygous pairs in the punnet square.

Ratios are always recorded as: Homozygous Dominant, Heterozygous, Homozygous Recessive

Monohybrid Cross

Below is an example of a punnet square being used to predict the genotypic outcome of cross breeding in regards to a wheat plant being tall or short. A cross that focuses on a single gene is called a monohybrid cross. Complete the punnet square and ratio for traits relating to drought tolerance in wheat.

Punnet square

	T	t
T	TT	Tt
t	Tt	tt

T Dominant
t Recessive
TT Tall
Tt Tall
Tt Short

Ratio

HOMOZYGOUS DOMINANT	HETEROZYGOUS	HOMOZYGOUS RECESSIVE
TT	Tt	tt
1	2	1
1:2:1		

Complete the punnet square and determine the likely phenotype – drought tolerant (dominant), not drought tolerant (recessive)			
	D	d	
D			
d			

HOMOZYGOUS DOMINANT	HETEROZYGOUS	HOMOZYGOUS RECESSIVE

Dihybrid cross

Scientists can also look at two genes at the same time, as long as their genotypes are independent of each other. The example below uses the tall/short trait and the drought/non-drought tolerant trait. This is known as a dihybrid cross – it is looking at two traits that are independent of each other at the same time.

	TD	Td	tD	td
TD	TTDD	TTDd	TtDD	TtDd
Td	TTDd	TTdd	TtDd	Ttdd
tD	TtDD	TtDd	ttDD	ttDd
td	TtDd	Ttdd	ttDd	ttdd

TASK

Using coloured pencils, highlight on the above table the groups of genotypes which correspond with a particular phenotype and then calculate the ratios.

PHENOTYPES	KEY	GENOTYPES	RATIO
Tall, drought resistant	Red	TTDD, TTDd, TtDD, TtDd	16
Dwarf, drought resistant	Blue	ttDd, ttDD	16
Tall, non-drought resistant	Green	TTdd, Ttdd	16
Dwarf, non-drought resistant	Yellow	ttdd	16

PHENOTYPE	Salinity resistant	Rust resistant
GENOTYPE	S or s	R or r

Complete your own dihybrid cross using salinity resistance and rust resistance.

	SR	Sr	sR	sr
SR				
Sr				
sR				
sr				

PHENOTYPES	KEY	GENOTYPES	RATIO
Salinity resistant, rust resistant	Red		16
Salinity resistant, rust non-resistant	Blue		16
Salinity non-resistant, rust resistant	Green		16
Salinity non-resistant, rust non-resistant	Yellow		16

STEP FOUR – PHENOTYPIC AND GENOTYPIC RATIOS

1. Cross the plant you created with another plant. Use punnet squares to show possible outcomes for all traits.
2. State the ratios for the possible phenotypes AND genotypes of the offspring.

WAXY _____ x _____

		Parent 2	
Parent 1			

Genotypic ratios _____ Phenotypic ratios _____

CCN _____ x _____

		Parent 2	
Parent 1			

Genotypic ratios _____ Phenotypic ratios _____

BORON _____ x _____

		Parent 2	
Parent 1			

Genotypic ratios _____ Phenotypic ratios _____

STOMATA _____ x _____

		Parent 2	
Parent 1			

Genotypic ratios _____ Phenotypic ratios _____

QUALITY _____ x _____

Parent 2

Parent 1

Genotypic ratios _____ Phenotypic ratios _____

HEIGHT _____ x _____

Parent 2

Parent 1

Genotypic ratios _____ Phenotypic ratios _____

GLOSSARY OF TERMS

Allele – one of a number of alternative forms of the same gene, represented by a single letter.

Genotype – a set of alleles that determines the expression of a particular characteristic or trait (phenotype).

Phenotype - physical appearance of an organism as a result of the interaction of its genotype and the environment.

Dominant gene - a relationship between alleles of a single gene in which one allele masks the phenotypic expression of another allele.

Recessive gene - an allele that causes a phenotype (visible or detectable characteristic) that is only seen in a homozygous genotype (an organism that has two copies of the same allele) and never in a heterozygous genotype.

Heterozygous - when two different alleles of a gene are present.

Homozygous – when both identical alleles of the gene are present.

Random segregation - Mendel's law of segregation, which states that allele pairs separate or segregate during gamete formation.

Genotypic ratios - describes the number of times a genotype would appear in the offspring after a test cross.

Phenotypic ratios - relative number of offspring manifesting a particular trait.

Punnet squares - diagram used to predict an outcome of a particular cross or breeding experiment.

8.0 ACTIVITY
A tonne of varieties

Farmers want to know how varieties will fit into their farming system.

How much does it yield and how does it adapt to the local environment?

How is this crop best maintained?

What agronomic attributes does it possess?

How are risks managed?

Do the characteristics of what is produced meet the market expectation?

At what time should it be harvested?

What is the best time and rate for sowing?

What existing varieties were used to create this new variety?

Plant breeders need to provide this type of information and keep a record of it so when a new variety is needed it can be determined which varieties would make appropriate parent plants.

The table below provides agronomic and character information about seven varieties of lentils available to grain growers in Australia. One of the oldest domesticated crops in the world, Australia grows red and green lentils with many varieties existing within each group.

VARIETY NAME	ASCOCHYTA ON FOLIAGE – FUNGI	BOTRYTIS GREY – MOULD	SEED BLIGHT – DISEASE	PLANT HEIGHT	BORON TOLERANCE	SALT TOLERANCE	POD DROP
Aldinga	MR	MS	MS	Med	I	I	MR
Boomer	MR	MR	MS	Tall	I	I	MR
Digger	MS	MR	MS	Med	I	I	MR
Nipper	R	R	R	Short	I	MT	MR
Northfield	R	S	R	Short	I	MI	MR
PBA Flash	MS	S	MS	Med	MI	MI	MR
PBA Jumbo	R	MS	R	Med	MI	MI	MR

Key S = Susceptible, MS = Moderately Susceptible, R = Resistant, I = Intolerant, MT = Moderately Tolerant

Pulse Australia, 2011

You are to create a new variety of lentil using two existing varieties listed in the table opposite. Focus on two attributes, choose whether they are dominant and record their alleles.

	VARIETY 1 _____	VARIETY 2 _____
Attribute 1		
Dominant or recessive		
Alleles		
Attribute 2		
Dominant or recessive		
Alleles		

Now, using this as a guide complete this dihybrid table.

Alleles				

PHENOTYPES	KEY	GENOTYPES	RATIO
Salinity resistant, rust resistant	Red		16
Salinity resistant, rust non-resistant	Blue		16
Salinity non-resistant, rust resistant	Green		16
Salinity non-resistant, rust non-resistant	Yellow		16

Summary:

Provide a short summary on the expected outcome of your plant breeding experiment.
Include discussion about your varieties, attributes and ratios.

9.0 RESEARCH
Better grain for everyone

Australia not only exports grain and pulses; it also exports and shares knowledge and skills in grains and pulses. It is essential for the ongoing development of the grains industry, with scientists involved in international research and development collaborations. These relationships enable scientists to share facilities, data, genetic material and knowledge. This is all part of a drive to ensure food security and sustainability in growing grains.

Australia is ...

- Using specially bred WA wheat varieties to make Udon noodles for Japan.
- Understanding the performance of different Australian wheat varieties in making baked goods in South East Asia
- Using Chinese and US barley varieties to breed salt tolerant barley varieties as the demand from China for high quality malting barley for beer increases.
- Part of an international effort to complete the genome-sequencing project of the field pea to increase the opportunities to breed new varieties in the future.
- Working with the International Centre for Agricultural Research in Dry Areas (ICARDA) to develop winter pulse varieties such as chickpeas, faba bean, lentil and field peas which are more resistant to disease.
- Joining Canada, Ethiopia, India and Turkey, to look at the genetic diversity of wild chickpea varieties to see if these can improve commercial crops.

Research and answer the following.

Search tips: ***Select key words and concepts. This first one has been done for you.***

- Australia is part of a network of countries which provides access to a wide range of germplasm collections (living genetic material such as seeds and tissue samples) for the betterment of plant breeding. This network is governed by the International Treaty on Plant Genetic Resources for Food and Agriculture. List three important goals of this treaty.
- Australia has been working with CIMMYT and ICARDA since the 1960s to enhance plant breeding opportunities and import wheat germplasm. The 1970 Noble Peace Prize recipient Dr Norman Borlaug was a research scientist with CIMMYT. Where are each of these organisations based and what is the aim of each?
- The Grains Research and Development Corporation, along with the Victorian Government, has invested in the Australian Grains Genebank. This facility holds genetic resources from the Australian Winter Cereals Collection, the Australian Tropical Crops and Forages Collection and the Australian Temperate Field Crops Collection. How many seeds and how many seed species from across the world does this facility house?

List three reasons you think national and international collaborations in scientific research and development are important for Australia.

1. _____

_____

2. _____

_____

3. _____

_____

10.0 ACTIVITY
New challenges, new varieties

It is believed plants started to be domesticated some 10,000 years ago in the Middle East! These plants, which included wheat, barley and lentils, were selected for their favourable characteristics, sown in a place with sufficient sunlight and given water. This was the simple beginning of plant breeding. Ancient farmers would collect the seeds from plants which had desirable traits and keep them to sow the following year.

Scientists can study domestication of grain and other crops by looking at the level of diversity within a gene pool of a species. This is particularly successful if records provide reference to a wild ancestral gene pool. Modern plant breeding techniques sometimes decrease the diversity of the gene pool because they focus on crosses of only elite varieties. To ensure that this does not become problematic, wild and heirloom varieties are kept in seed banks or gene banks. To maintain records, scientists around the world now carry out genome sequencing to create a map of the diversity within a species of grain.

TASK

Research a current grain crop grown in Australia. These crops include wheat, barley, oats, sorghum, maize, triticale, millets, cereal rye, canary seed, lupins, field peas, chickpeas, faba beans, vetch, peanuts, mung beans, navy beans, pigeon peas, cowpeas, lentils, canola, sunflower, soybean, safflower and linseed.

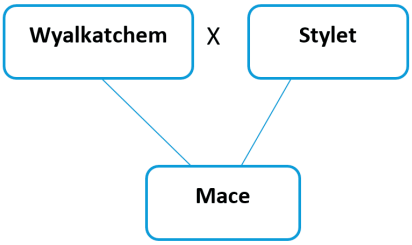
1. Research what part of the world this grain crop originated from.
2. Give an example of an area where this crop grows now in Australia. Provide an overview of the type of environment this crop originally grew in and compare it to the environment it is exposed to when grown in Australia.
3. Find an article about the challenges of growing this crop in Australia and plant breeding. Provide a summary of the key ideas in this article. Ensure you reference correctly.
4. Imagine you are a plant breeder. Create an outline of a plant breeding proposal that could help overcome this challenge. Think about the desired attribute(s) and provide a monohybrid or dihybrid table summarising its potential.

11.0 ACTIVITY
Variety Feature

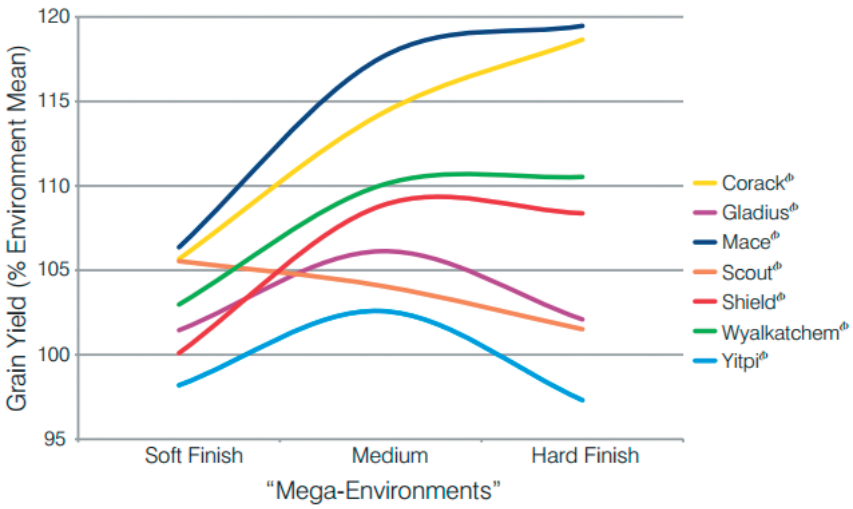
As the result of research and development, new varieties of plants are available to grain growers on a regular basis. Mace has been the leading wheat variety in both WA and SA in recent seasons. Mace is grown by farmers throughout Australia because of its:

- Broad adaptation (meaning it can suit a variety of growing conditions).
- High yield under a wide range of conditions.
- Lower susceptibility to the defect black point, pre-harvest sprouting or screenings losses.

Mace is derived from a cross involving Wyalkatchem as the major parent and Stylet as the minor parent.



PREDICTED GRAIN YIELD FOR DIFFERENT VARIETIES



Source: AGT, http://www.agtbreeding.com.au/assets/docs/general/Mace-FS.pdf

Look at graph 'Predicted grain yield for different varieties'.

Comment on the yield difference between the parent plant Wyalkatchem and the offspring Mace.

TASK:

Research the parent plants Wyalkatchem and Stylet by using the Australian Grains Technology and other websites.

Look at the traits of each of these varieties. Which traits from each plant do you think plant scientists were interested in when breeding the new variety Mace?

VARIETY	DESIRABLE TRAITS *Link: http://www.agtbreeding.com.au/varieties/wheat*
WYALKATCHEM	
STYLET	

Molecular markers

When scientists are researching the genetics of a plant, they use known fragments of DNA as molecular markers. Scientists use molecular markers to determine the location of certain genes within the genome (e.g. location throughout the entire DNA of a wheat plant).

Mace was developed by conventional crossing techniques but then molecular marker technology (DNA fingerprinting) was used to identify which offspring had inherited the desired traits. Research molecular markers and DNA fingerprinting and provide a statement of what these are and how they work in plant breeding programs.

Plant characteristics

Mace is a “fully awned spring wheat”.

What are awns? Draw a labelled diagram of these.

12.0 INSIGHT DNA Basic

Dr Norman Borlaug conducting field work

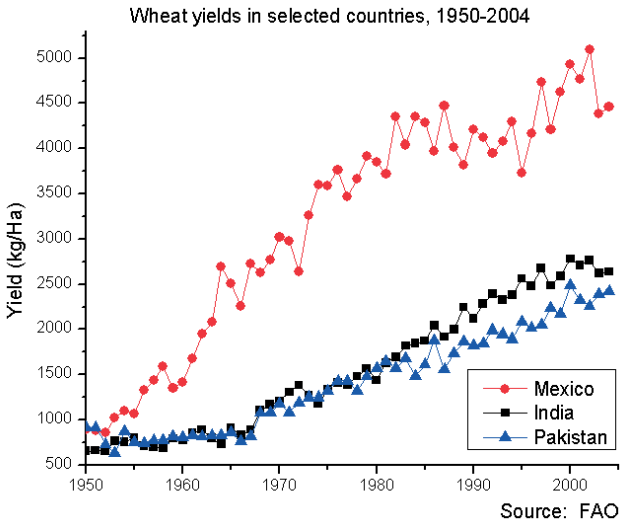
The evolution of plant breeding methods has enabled scientists and farmers to improve the efficiency and sustainability of growing grains in Australia. In the 1960s, a plant geneticist and plant pathologist called Dr Norman Borlaug was working in Mexico when he was tasked with the challenge of breeding new wheat varieties to suit particular and varying conditions. For many years, he was the lead scientist in this program creating new varieties and training many young scientists along the way.

Dr Borlaug was successful in creating wheat which produced a high yield and had disease resistance. These successful varieties bred in Mexico were soon adopted in many other parts of the world including Asia and Latin America.

Dr Borlaug saw the success of these new cereal varieties as a way to combat the growing hunger challenges of the world. This period of addressing the challenge of famine around the world with innovative agriculture is known as the 'Green Revolution'. In 1970, Dr Norman Borlaug was awarded the Nobel Peace Prize for feeding the hungry of the world.

"A temporary success in man's war against hunger and deprivation." –

N. BORLAUG, THE ONLY AGRICULTURAL SCIENTIST TO HAVE WON A NOBEL PEACE PRIZE!



While plant breeding in the green revolution was reliant on assessing the phenotype of a plant, scientists can now make assessments on the plant's genotype.

Keyword recap

PHENOTYPE	
GENOTYPE	

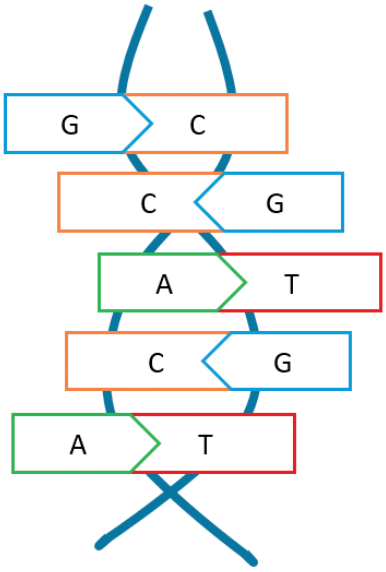
To assess the genotype of a plant, scientists must extract the instruction manual of how the plant is made and how it functions – its DNA! Today DNA can be extracted in many ways. Plant scientists use the same techniques as medical and forensic scientists to investigate the differences between individual plants and how genes work.

DNA in grains

We know that DNA is made up of genes built by four types of chemical units known as bases: A, T, G, C. In different combinations, these act as the instructions for making proteins.

These proteins contribute to different characteristics (e.g. flower colour, height).

In a wheat plant what might be some of these characteristics?



When scientists develop new varieties of crops, they can look at a plant's DNA to predict what genes it has inherited from its parents. This technique, known as marker-assisted selection, is helping plant breeders develop better varieties of crops to growers faster. Marker-assisted means scientists know the pattern of certain genes and use it to identify locations on the DNA. We can screen samples of DNA from many plants to identify which ones have the characteristics we want.

To discover more about DNA we need to get it out of the cell**.** There are several ways that an experienced scientist can do this, but this is a simple way that a young scientist like yourself can discover it.

A simple way to extract DNA

The DNA sits securely within the nucleus of a cell – the centre of the cell. To extract the DNA, we need to break open the membrane around the cell. Molecules within ordinary washing up detergent can combine with the molecules of a cell membrane, pulling at it which causes the cell to rupture and release the nucleus inside.

Once the DNA is free from the cell, we need to protect it from acid pH by buffering the solution. Enzymes are added to digest proteins in the solution which may damage the DNA.

Alcohol is added to the solution to make the DNA become solid (precipitate). The sample is finally purified to remove any cellular debris.

Did you know?

Barley has about 30,000 genes.

Wheat has about 100,000 genes.

Humans have about 30,000 genes.

13.0 PRACTICAL
Simple DNA extraction

1. Put on a lab coat, gloves and safety glasses. You should also be wearing enclosed shoes and working in a well-ventilated room.

2. Using the measuring cylinder, measure 100ml of water and add to the plastic cup.

3. Add 1 tablespoon of wheat germ to the water in the cup. Mix by stirring gently.

4. Add 1ml (or a squirt) of detergent and stir gently for 1 minute. Avoid making bubbles.

5. Use a pipette or a piece of paper towel to remove any foam from the solution.

6. Add 1 teaspoon of meat tenderiser to help uncoil the DNA.

7. Add 1 teaspoon of baking soda. This will buffer the solution so it is not too acidic for the DNA.

8. Gently mix by swirling the solution.

9. Let the solution settle in the plastic cup for one to two minutes, or until the wheat germ settles to the bottom.

10. Once settled, pour 25ml of the supernatant (the liquid from the top of the settled solution) into a 50ml tube.

11. Using the squeeze bottle containing methylated spirits, SLOWLY AND GENTLY drizzle 10ml down the side of the tube. Do this carefully so the methylated spirits forms a layer on top of the wheat germ solution. Try not to mix the two layers.

12. Observe the interface of the alcohol and wheat germ solution. You should see white threads appear. This is DNA precipitating!

This experimental protocol was reproduced with permission from the Australian Centre for Plant Functional Genomics 2015.

APPENDIX

Practical

Check out their genetics! COMPLETE

TRAIT	DESIRED TRAIT	ALLELE
Waxy	Waxy	**W**
Cereal Cyst Nematodes	CCN Resistant	**C**
Boron	Boron Tolerant	**B**
Stomata	Small stomata	**s**
Quality	Strong protein quality	**P**
Height	Dwarf	**h**

Creating alleles

COMPLETE

	WAXINESS		CEREAL CYST NEMATODE		BORON	
Phenotype	Waxy	Non-waxy	Resistant	Non resistant	Boron tolerant	Boron intolerant
Allele	**W**	**w**	**C**	**c**	**B**	**b**
Genotype	WW or Ww	ww	CC or Cc	cc	BB or Bb	bb

	STOMATA		QUALITY		HEIGHT	
Phenotype	Large Stomata	Small Stomata	Strong protein quality	Poor protein quality	Tall	Dwarf
Allele	**S**	**S**	**P**	**p**	**H**	**h**
Genotype	SS or Ss	ss	PP or Pp	pp	HH or Hh	hh

Step Three – Fertilisation

EXAMPLE

TRAIT	GENOTYPE	PHENOTYPE
Waxy	Ww	Waxy leaf
Cereal Cyst Nematode	cc	CCN non-resistant
Boron	Bb	Boron tolerant
Stomata	Ss	Large stomata
Quality	pp	Poor protein quality
Height	HH	Tall

APPENDIX

Activity

Punnet squares and genotype ratios

HOMOZYGOUS DOMINANT	HETEROZYGOUS	HOMOZYGOUS RECESSIVE
DD	Dd	Dd
1	2	1
1:2:1		

Monohybrid cross

COMPLETE

COMPLETE THE PUNNET SQUARE AND DETERMINE THE LIKELY PHENOTYPE – Drought tolerant (dominant), not drought tolerant (recessive)			
	D	d	D – Dominant d – Recessive DD – Drought tolerant Dd – Drought tolerant dd- Drought intolerant
D	DD	Dd	
d	Dd	dd	

Dihybrid cross

COMPLETE

PHENOTYPE	Salinity resistant	Rust resistant
GENOTYPE	S or s	R or r

Complete your own dihybrid cross using salinity resistance and rust resistance.

	SR	Sr	sR	sr
SR	SSRR	SSRr	SsRR	SsRr
Sr	SSRr	SSrr	SsRr	Ssrr
sR	SsRR	SsRr	ssRR	ssRr
sr	SsRr	Ssrr	ssRr	ssrr

PHENOTYPES	KEY	GENOTYPES	RATIO
Salinity resistant, rust resistant	Red	SSRR, SSRr, SsRR, SsRr	$^{9}/_{16}$
Salinity resistant, rust non-resistant	Blue	ssRr, ssRR	$^{3}/_{16}$
Salinity non-resistant, rust resistant	Green	SSrr, Ssrr	$^{3}/_{16}$
Salinity non-resistant, rust non-resistant	Yellow	Ssrr	$^{1}/_{16}$

APPENDIX

Step Four – Phenotypic and genotypic ratios

Example

Each pair of students is to share results with another pair of students. E.g. Pair 1 Ww *and Pair 2* ww

WAXY **Ww** x **Ww**

		Parent 2	
		W	w
Parent 1	W	WW	Ww
	w	Ww	ww

Genotypic ratios WW= 1 Ww = 2 ww=1 Phenotypic ratios Waxy = 3, Non-waxy = 1

Tonne of Varieties

EXAMPLES

	VARIETY 1 ALDINGA	VARIETY 2 NIPPER
Attribute 1	**Moderately resistant to fungi**	**Resistant to fungi**
Dominant or recessive	**Dominant**	**Recessive**
Alleles	**F**	**f**
Attribute 2	**Medium height**	**Short height**
Dominant or recessive	**Recessive**	**Dominant**
Alleles	**T**	**t**

Now, using this as a guide complete this dihybrid table.

Alleles	TF	Tf	tF	tf
TF	TTFF	TTFf	TtFF	TtFf
Tf	TTFf	TTff	TtFf	Ttff
tF	TtFF	TtFf	ttFF	ttFf
tf	TtFf	Ttff	ttFf	ttff

14.0 Good reads

'Research and Development', Grains Research and Development Corporation, www.grdc.com.au

'The Science of Plant Breeding', Australian Grain Technology,
http://www.agtbreeding.com.au/about/the-science-of-breeding

'The Wheat and Barley Book', Australian Centre for Plant Functional Genomics,
http://www.acpfg.com.au/uploads/documents/publications/wheat_barley_book.pdf

'Researchers reveal how the humble barley became domesticated', ABC Rural, Cooke, T, July 2015,
http://www.abc.net.au/news/2015-07-31/genetic-barley-discovery-domestication/6662430

'Wild rice discovery could unlock key to global food security', RN Bush Telegraph, Wilson, C, November 2014,
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