NSW GOVERNMENT | Department of Primary Industries

Agri-food, fibre and fuel technologies

Supporting document

NSW DPI Schools Program

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Content

Agri-food, Fibre and Fuel Technologies

Overview

Agri-food, Fibre and Fuel Technologies is one of three electives offered in the 2013 NSW Agriculture Stage 6 Syllabus.

It aims to highlight the range of developing technologies which are transforming agricultural management and production. Students have the opportunity to study a range of concepts and technologies and analyse their impact on agricultural industry. This document provides teachers and students with links to a number of resources and activities that align to the NSW Agriculture Elective 1: Agri-food, Fibre and Fuel Technologies syllabus outcomes and content to support their learning throughout this elective. This supporting document has been developed as a digital resource to provide access to the large number of hyperlinks which it contains. It should be used in this format. Accompanying this document there is a Suggested answers document available at the NSW Department of Primary Industries School Programs page.

Past questions and sample answers

Teachers, students and markers are able to view past HSC examinations and Sample HSC Examination Questions on the NSW Board of Studies, NSW Educational Standards Authority (NESA) website.

Sample answers have been provided for learning activities where applicable for this document. It should be noted that these sample answers are suggested answers and not necessarily the very best answer, nor are they the only possible answers.

HSC Verbs and Key Words

It is integral students address the following key terms and verbs when answering questions. The following glossary developed by the NSW Education Standards Authority is provided to assist with the answering of activities throughout this booklet.

Key Word	Definition
Account	Account for: state reasons for, report on Give an account of; narrate a series of events or transactions
Analyse	Identify components and the relationship between them; draw out and relate implications
Apply	Use, utilise, employ in a particular situation
Appreciate	Make a judgement about the value of
Assess	Make a judgement of value, quality, outcomes, results or size
Calculate	Ascertain/determine from given facts, figures or information
Clarify	Make clear or plain
Classify	Arrange or include in classes/categories
Compare	Show how things are similar or different
Construct	Make; build; put together items or arguments
Contrast	Show how things are different or opposite
Critically (analyse/ evaluate)	Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/evaluate)
Deduce	Draw conclusions
Define	State meaning and identify essential qualities
Demonstrate	Show by example
Describe	Provide characteristics and features
Discuss	Identify issues and provide points for and/or against
Distinguish	Recognise or note/indicate as being distinct or different from; to note differences between
Evaluate	Make a judgement based on criteria; determine the value of
Examine	Inquire into
Explain	Relate cause and effect; make the relationships between things evident; provide why and/or how
Extract	Choose relevant and/or appropriate details
Extrapolate	Infer from what is known
Identify	Recognise and name
Interpret	Draw meaning from
Investigate	Plan, inquire into and draw conclusions about
Justify	Support an argument or conclusion
Outline	Sketch in general terms; indicate the main features of
Predict	Suggest what may happen based on available information
Propose	Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
Recall	Present remembered ideas, facts or experiences
Recommend	Provide reasons in favour
Recount	Retell a series of events
Summarise	Express, concisely, the relevant details

Source: NSW Education Standards Authority, 2018

Innovation, ethics and current issues

1. Biotechnology

Syllabus point

Define DNA, gene, genetically modified organism (GMO), gene markers, genetic engineering and protein synthesis.*

Glossary:

Biotechnology - A broad term for a group of technologies which uses living things or biological processes, for the purpose of industry, technology, medicine or agriculture.

Chromosomes - Chromosomes consist entirely of wound up strands of DNA. They are microscopic 'x' shaped structures found in the cell nucleus. Sequences of DNA are genes. All living things have a set number of chromosomes. For example wheat- 42 chromosomes, maize- 20 chromosomes, sheep- 54 chromosomes, cattle- 60 chromosomes, humans- 46 chromosomes, fruit fly- 8 chromosomes, Atlas blue butterfly- 452 chromosomes. The number of chromosomes does not correlate with the complexity of the organism.

Deoxyribonucleic acid (DNA)*- A long chain of molecules containing genetic information for an organism. The genetic information codes for development, function and characteristics of the individual cell and essentially whole organism. DNA is wound into chromosomes within the cell nucleus. The individual molecules which make up the DNA are called nucleotides.

DNA structure - DNA is made up of two complementary strands known as a double *helix* which visually looks like a spiralling ladder. Each strand is made up of nucleotides joined together by matching base pairs.

Gene*- A sequence of DNA that encodes all the information to build a specific protein, these are the basic units of heredity.

Gene markers*- DNA sequences with known physical locations on chromosomes. They have an easily identifiable phenotype and their inheritance pattern as a result, can be followed. They are used to trace or identify specific regions of genes in heredity.

Genetic engineering*- altering the genes or DNA of an organism using modern biotechnology techniques. This includes controlling gene activity, modifying genes and transferring genes in order to alter or investigate gene function. Used for an ever-evolving list of applications to generate GMOs or provide information to speed up conventional breeding.

Genetically modified organism (GMO)*- an organism that has been altered by genetic engineering techniques.

Genotype - The genetic makeup of an organism.

Heredity - The transmission of genetic material from parents to offspring, by either asexual or sexual reproduction.

Nucleotides - Molecules made up of three portions; a nitrogenous base- either adenine (A), thymine (T), guanine (G) or cytosine (C); and a sugar and phosphate backbone. Nucleotides between the two complementary DNA strands match together dependant on their nitrogenous base. A matches with T and G with C.

Phenotype - The physical characteristics of an organism. Resultant from the interaction between genotype and environment.

Protein synthesis*- Protein synthesis is the process of individual cells building specific proteins. The complex process involves DNA strands 'unzipping' and their codes for protein genetic information are copied and transcribed by two types of RNA to produce strands of amino acids which are the structural units of proteins. The type of protein and its function depends on the exact composition and order of amino acids in the sequence as encoded by the DNA. The process occurs in multiple locations within the cell.

Ribonucleic acid (RNA) - a chemical which is copied from a single DNA strand. RNA delivers DNA's genetic message to where proteins are made or synthesised.

Transgene - The gene that has been transferred into a new host leading to a GMO.

Transgenic - An organism containing one or more deliberately inserted genes from another species.

Learning activities

1. **Write the definitions for the following terms:**

- DNA

- Gene

- Genetically Modified Organism (GMO)

- Gene markers

- Genetic engineering

- Protein synthesis

2. **Draw and label a flow diagram illustrating the relationship between: cell, nucleus, chromosome, DNA and gene.**

3. **Explore this link to The University of Utah's Learn Genetics page to revise on the fundamentals of "Basic genetics" through interactive activities and online simulations.**

Syllabus point

Describe the implications of biotechnology in the agri-foods, fibre and fuel industries.

Biotechnology and Agribiotechnology

Biotechnology is a broad term used to describe the use of living things or their products to create or change products. It encompasses the transformation of materials by micro-organisms (eg. fermentation), methods of propagation, such as plant cloning or grafting, and may involve genetic alteration through methods such as selective breeding. It is an evolving industry creating applications to address a range of economic and social issues such as food production and security, human health, limited natural resources, environmental challenges and alternative fuel issues.

Agricultural biotechnology (agribiotech) is a natural progression of conventional breeding. Over time, plant and animal breeding has become increasingly sophisticated, moving from farmers who saved seeds from crop plants that performed the best in the field (selective breeding), to the deliberate crossing of different varieties from the same or closely related species (hybridisation), to gene selection through mutagenesis, to modern agribiotech. All available breeding techniques remain important to modern breeding techniques—agribiotech is technology used to speed up and make more accurate the development of new and improved plant and animal varieties and high-value agricultural products (ABCA, 2018).

Areas where agribiotch can be applied include:

- Animals and animal health
- Aquaculture
- Fibre crops and forestry
- Food crops and plant production
- Sustainability and resource management

- Renewable fuel production

Traditional forms of biotechnology include: domestication of plants and animals, manufacturing of medicines and pharmaceuticals, manufacturing bread, cheese, yoghurt, wine, cross breeding and conventional breeding and strategies such as selective breeding and hybridisation. Traditional biotechnology has been utilised by humans for thousands of years.

Modern techniques include broad areas of: biofortfication, genomics, and the use of DNA markers, gene technologies and epigenetics. The application of these technologies is vast and constantly evolving. New technologies show promise for meeting areas of greatest concern for sustainable food, fibre and fuel production in the 21st century.

Biotechnology case studies:

Follow these links to investigate iconic examples of agribiotech.

- Human-like milk made by GM cows
- AquaAdvantage Salmon- since the YouTube video was published, the American FDA approved AquaAdvantage salmon for human consumption. It became commercially available and not currently labelled as a GMO food in the U.S. (2015) and Canada (2017).
- Bollgard® 3 XtendFlex® Cotton
- Enviropig
- Biofuels 101

Learning activities

1. **Use your understanding from the 'Biotechnology case studies' and carry out further research if required, to complete the following table.**

Biotechnology	Description	Benefits	Possible risks
Cows producing milk with high lysine content			
Enviropig			
AquaAdvantage salmon			

Biotechnology	Description	Benefits	Possible risks
Bollgard Cotton			
Biofuels			

2. **Complete the following table to list at least three general potential benefits and three risks of biotechnology. Use the '25 years of GMO crops: Economic, environmental and human health benefits' article for assistance.**

Benefits	Risks

Syllabus point

Outline the importance of food safety and labelling of GMOs

Food safety is vital to protect the health and well-being of the economy, environment and community through the provision of stringent codes of practice, production specifications and labelling requirements for producers and manufacturers of consumable products.

Food labelling is one of the most important factors affecting the purchasing decisions of the consumer, it is often the only piece of information a consumer has regarding a product. Accurate food labelling is essential to protect public health and safety and provide the consumer with information to make an informed decision regarding food products. It is the consumer's right to information and labelling is a tool that allows the consumer to make an informed choice.

The primary role of a food label is to inform consumers of the foods:

- Nutritional values and ingredients
- Manufacturer
- Country of origin
- Health claims
- Allergens present
- Additives
- Religious, animal welfare or environmental claims
- Descriptions on how the food was produced (e.g. GMO, organic)
- Preparation and storage instructions
- Expiry dates.

All this data helps consumers decide whether they will purchase certain foods, without it the consumer is at risk to potential cultural, ethical and health and safety issues.

Food producers consult and comply with their country's regulations on proper food labelling before sending labels to be professionally printed. In Australia, content is set by the Food Standards Code and the regulators that ensure labels provided specific content is carried out by Food Standards Australia New Zealand (FSANZ). Food labelling laws are designed so consumers are provided accurate, vital information so they can make an informed choice about the foods they consume. Food labelling transparency allows food producers to increase consumer trust in their product.

Go to the Department of Primary Industries Food Labelling page to learn more about labelling requirements in Australia.

The issue with GM

GM crops are currently grown over 185 million hectares in 29 countries worldwide and imported and consumed by countries that don't grow them. The technologies provide so many benefits to sustainable and efficient food, fibre and fuel production now and for the future.

The issue of genetically modified organisms and their presence in products, therapeutics, food chains and for consumption however, causes much controversy. Many view GM as an exciting innovation and have no issue with consuming products produced with modified gene technologies, many people however, do not. Reasons against GM consumption include a range of cultural, historic, religious, ethical and health reasons; as well as lack of knowledge of the technologies and the perceived risk of GMOs. As a result, some countries have implemented labelling guidelines to alert consumers to the presence of GMO's in products.

Australia has a nationally consistent legislative scheme for modified gene technology. Regulation of GMOs in Australia is handled by the Office of the Gene Technology Regulator (OGTR), corresponding state and territory legislation and Food Standards Australia New Zealand (FSANZ). The OGTR initially commercially licences GM technology after carrying out risk analysis of the product; and provides lists of approved GM crops and a map of their production locations in Australia. FSANZ assesses food safety and regulates mandatory labelling, requiring all GM food sold in Australia to be labelled as containing GMOs if novel DNA or protein is present in the final product.

FSANZ food safety assessments

FSANZ GMO safety assessment ensures any product approved for consumption containing GMO material is safe and nutritious as comparable to conventional foods already in the Australian and New Zealand food supply.

The safety assessments are carried out with the purpose to identify if the GM food is comparable and has all benefits and associated risks as the conventional food counterpart. The safety assessment purpose is not to establish the absolute safety of the GM food. Absolute food safety cannot be guaranteed in either conventional or GM food products.

Assessment is characterised by:

- Identification of new or altered hazards associated with the food as a result of the genetic modification;
- Assessment of whether there is any risk associated with any identified hazards under the intended and unintended conditions of use; and
- Determination of any new conditions of use required to enable safe use of the food

Currently there are no GM animal products for consumption certified and approved in Australia, however, there are GM plant products.

Go to: FSANZ Safety assessments of GM foods for further reading.

FSANZ GM labelling

Australia has some of the most stringent GM food labelling requirements worldwide. Any product containing more than one percent of GM ingredients must be clearly labelled. There is zero tolerance for the presence of an unapproved GM food or food ingredient.

Exemptions for mandatory labelling in Australia include:

- Highly refined foods such as sugars and vegetable oils where genetic material is removed during the refining process.
- Flavours containing novel DNA or protein in a concentration of no more than 0.1 percent.
- Instances where there is no more than one percent (per ingredient) of an approved genetically modified food unintentionally present
- Foods prepared for immediate consumption such as take away or restaurant meals (Agricultural Biotechnology Council of Australia Limited, 2017)

Go to: FSANZ Genetically modified food labelling for further reading.

Learning activities

1. **Complete the following table on current GM crops produced in Australia for consumption.**

Crop Type	Year/s originally commercially grown	Modification	Uses

2. **Complete the table to identify five GM crop products FSANZ has approved for Australian consumption from overseas. For each, give an example of product uses.**

Imported GM crop	Products and uses

Follow the link to the article "[How are GMOs labelled around the world?]" to see examples of GM labelling and answer activities 3-4

3. **Contrast the two categories for GM labelling.**

4. **Clarify what labelling categories from Activity 3 are used in Australia and New Zealand.**

Apply your understanding of the importance of safety and food labelling to answer activities 5-6

5. **Explain why it is important to assess GM food product safety prior to commercial release to consumers**

6. **Outline the importance of food safety and labelling in relation to the use of genetically modified organisms.**

2. Ethical concerns and controversy surrounding biotechnology use in agricultural production

Syllabus point

Discuss the issues relating to food production using GMOs

There are many issues which surround GM technologies in relation to food production in agriculture. The issues, both positive and negative, exist surrounding the need for GM biotechnology to be used to produce high quality, high yield crops and organisms at low cost while protecting the ecosystem and human health.

Issues surrounding food production with the utilisation of GMOs can be divided into main areas:

- Consumer concerns- Consumer Health and safety concerns and consumer rights
- Humanitarian- producing foods, and products for starving and developing vs industrialised nations
- Environmental- production with less impact on resources and environment, but also the possible impacts on biodiversity, food chains, and environment
- Economics – multinational corporations controlling technologies; greater profit and ease of production for farmers
- Legal concerns- intellectual property rights and patents which could potentially lead to monopolisation of technology knowledge and control

Follow the links to gain more understanding of the positive and negative issues surrounding food production using GMOs.

- Genetically Modified Food- watch this YouTube 'Intelligence Squared' debate which gives a balanced and unbiased overview of current issues surrounding GMO production by acclaimed national scientists.

- Genetically modified crops shrink farming's pesticide footprint- this article outlines Australian environmental impacts associated with GM food production.
- Animal breeders are blocked worldwide from using genetic engineering. Here's why – this article explores issues surrounding production of GM animals worldwide and identifies many projects and applications of GM technology involving livestock production.
- Golden rice and the struggle over genetically modified food- this article investigates issues surrounding GM food products such as golden rice and the restriction of its commercial release and investigates the Australian development of a GM banana high in Vitamin A.
- Watch Food Evolution, Black Valley films, directed by Scott Hamilton Kennedy. This is an academy award nominated documentary which discusses the science, ethics and societal views on GMO's. This link takes you to the trailer; the full documentary is available through subscription. It is an excellent resource which investigates GMO technologies.

Learning activities

1. Conduct research to investigate a range of current issues surrounding GM food production and complete the following table. The first example has been given to you

Issue	List positive issues	List negative issues	Current GM example/s
Effect on agricultural production e.g. yield, quality and efficiency	• Increase yield of plants through manipulation of genetic material of conventionally bred varieties. • Increase efficiency of production. • Increases in yield and efficiency occur at a quicker rate than conventional breeding.	• Legislation/contracts required to produce high yield and efficient GM varieties. • Long time frame to patent and certify products prior to commercial availability. • Patents involved with using GM products can constrict management and production options.	• GM cotton and GM canola varieties (Australia) • GM cows with enhanced beef flavour (Japan) • GM sheep with increased milk yield and higher quality wool (Australia)
Environmental impact in terms of sustainability and resource degradation			
Chemical usage (cropping)			

CO_2 and greenhouse gas emissions (cropping and animals)			
Public perception			
Animal GM			
Animal welfare			
Effect on agricultural production e.g. yield, quality and efficiency			

Use your research from Activity 1 to answer the following question. Use multiple issues to support your answer and back up your discussion with current agricultural examples. Use the scaffold to structure your response

2. **Discuss the use of genetically modified crops in agricultural production (NESA 2017 HSC Agriculture Q28.b 12 marks)**

Discuss: identify issues and provide points for and/or against

Issues identified

AND/OR

Points for:	Points against:

Syllabus point

Examine the regulations that surround the development and use of GMOs and biotechnology

Development of GMOs and biotechnology - Australian legislation

Australia has a nationally consistent legislative scheme for development of GMOs, comprised of the Commonwealth *Gene Technology Act 2000 and Gene Technology Regulations 2001* and corresponding state and territory legislation. The laws and regulators all work together to protect the health and safety of consumers, the environment and the economy. For further reading go to: "*How are GM crops and products regulated in Australia*", (Agricultural Biotechnology Council of Australia Limited, 2017).

No GMO animal products have currently been approved for production for consumption in Australia, only GMO crop products. GMO animals are produced for scientific purposes. Research involving GMO animals is subject to the same Commonwealth legislation, OGTR risk assessment and licencing, federal legislation; state and territory legislation as all GMO's. In addition, the Australian code of practice for the care and use of animals for scientific purposes regulates welfare.

Regulation at a federal or national level of the acts is carried out by a number of authorities including:

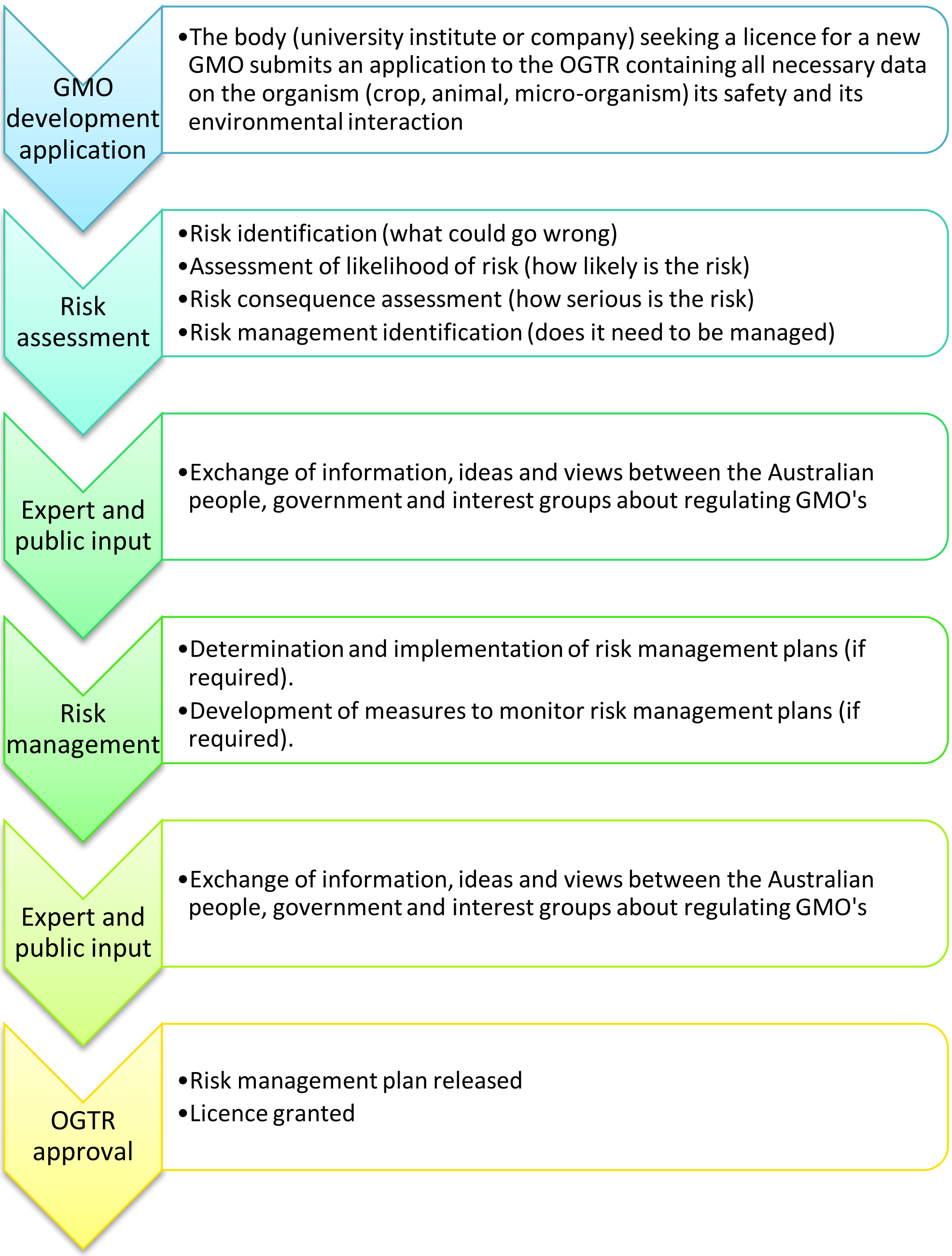
- The Office of the Gene Technology Regulator (OGTR)
- Therapeutic Goods Administration (TGA)
- Food Standards Australia New Zealand (FSANZ)
- Australian Pesticides and Veterinary Medicines Authority (APVMA)
- The National Industrial Chemicals and Assessment Scheme (NICNAS)

State and Territory regulation of GMO’s governs whether commercial GMO production is approved in the state or territory, regardless of OGTR commercialisation and licencing.

In terms of GM crops and food products, the OGTR, FSANZ and APVMA are the three main regulators responsible for assessment, licencing and approval in Australia.

The OGTR carries out initial risk analysis before commercial licencing of the gene technology product is granted. FSANZ assesses food safety and product labelling.

The following diagram shows the OGTR process for assessing Australian GMO applications for licencing. Source: [Agricultural Biotechnology Council of Australia Limited, 2017].



Use of GMOs and biotechnology- Australian legislation

The commercial use and production using GMO crops in Australia is highly regulated by contracts and patents, issued by the company or institute that developed and holds the licence and Intellectual Property rights for the GMO.

A patent is a right that is granted for any device, substance, method, knowledge or process that is new, inventive, and useful. A patent is legally enforceable and gives the owner, exclusive rights to commercially exploit the invention for the life of the patent (IP Australia, Australian Government). Patents and IP rights help protect Research and Development (R&D) investment and ensure the legal and economic viability of R&D. The Patents section of the IP Australia, Australian Government website provides a wealth of information about patents including case studies which provide examples of the ways patents protect and enhance research and development.

The largest multi-national agricultural seed and chemical companies which provide GMO seeds and own the IP rights globally are: Bayer/Monsanto (Bayer have recently taken over the Monsanto company), Baden Aniline and Soda Factory (BASF), DuPont, Dow Chemical Company and Syngenta.

These companies have rigorous legal contracts and grower agreements, which growers must agree and adhere to in order to purchase and grow their GMO product.

Grower agreement contracts grant the grower a limited license to use the seed or product containing the patented technology. Agreements typically include legislation including:

- Clauses to use the patented seed technology solely for planting a single commercial crop with no saving of any crop seed for planting in any subsequent year by the licenced grower
- Clauses to prevent the grower supplying patented seed to any other person or entity without written consent from the patented supplier
- Growers must complete accredited courses prior to use of the patented technology
- Gowers agree to annual audits and farm surveys regarding the patented seed use by the supplier and the OGTR throughout the licencing year of growing the patented seed and agreed timeframes after seed use
- Patented seed must be used in strict accordance with planting, handling and management regulations as according to the OGTR, State legislation and grower agreements with the patent holder and seed supplier. These agreements state management requirements which prevent GM seed environmental contamination.
- Growers must use APVMA approved chemicals for pest and disease management. Some supplier companies list specific pesticide brands (usually their own chemicals).

Growers must adhere to the grower agreement legislation in order to use the patented seed product. Non-compliance and patent infringement result in the grower not being able to obtain future limited use licences and opens the grower to litigation.

Follow the link to investigate a Victorian ROUNDUP READY® CANOLA GROWER LICENSE AND STEWARDSHIP AGREEMENT.

Learning activities

Development of GMOs - Australian legislation activities

1. Name the Commonwealth legislation for GMO's

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2. List the five national regulatory authorities for GMOs in Australia

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Follow the link to find the article on "*State Regulation*" to see examples of state and territory positions regarding GMO production to answer activity 3.

3. Label the map of Australia to show the current position of each state and territory on GM crops.

Use of GMOs- Australian legislation activities

Follow the link to investigate the article "*Impacts of genetically modified crops and seeds on farmers*".

4. **Use the article to complete the table and summarise concerns involved with grower contracts for use of a patented crop.**

Issue
Contract issues
Seed reuse and retention
Binding arbitration (settlement)
Acceptance of liability

Syllabus point

Examine the role of biosecurity

Biosecurity is the protection of the economy, environment and community from the negative impacts of pests and diseases, weeds and contaminants.

Biosecurity involves preventing new threats from accessing Australia; controlling outbreaks when they do occur and controlling spread and incursion of pests, diseases, weeds and contaminants already present in Australia. Globalisation, urbanisation and climate change are increasing the risk of a biosecurity event in Australia at a national, state, district and individual property level. The Australian Government has regulatory responsibility for Biosecurity pre-border and border activities, while state and territory governments are responsible for post-border activities such as surveillance and response.

While robust response plans are in place to combat outbreaks, preventing pest, disease and weed incursions in the first place, is a shared priority from the national level all the way to the state, regional and personal level. Everyone has a role in biosecurity and it is a shared responsibility.

Australia's geographic isolation allows Australia to be free from many diseases, pests, weeds and contaminants of serious global significance. Freedom from these exotic pests and diseases is a vital part of the future profitability and sustainability of Australian agriculture. Biosecurity allows us to preserve and access unique and essential international and domestic markets.

Farm Biosecurity

Producers play a key role in protecting Australian plant and livestock industries from pests, weeds and diseases. Farm biosecurity surrounds a set of measures designed to protect a property and prevent the entry and spread of biosecurity threats. The key drivers of good biosecurity are:

- Protection e.g. always request a commodity vendor declaration and ensure any stock feed purchased is fit for purpose

- Prevention e.g. isolate new plants or animals away from production areas for 21 days before mixing them with existing stock
- Prediction e.g. regulate the entry of threats on property by having minimal entry points and conducting risk assessments before visitors or equipment access the property to determine the threats and allow for assessment of the impact of a potential threat to production.
- Preparation e.g. farm biosecurity plans and frameworks in place; regular monitoring and surveillance for threats; keeping of relevant health and traceability production records; training of employees to increase education of threats.
- Response e.g. reporting and treatment of threat incursions
- Recovery e.g. seeking financial assistance or accessing support networks and events after a significant threat incursion e.g. foot and mouth disease.

Good farm biosecurity strengthens regional biosecurity, which in turn supports national biosecurity.

If a new pest or disease becomes established on farm, it can affect business through:

- Increasing costs (for treatment, monitoring, production practices, additional chemical use and labour)
- Reducing productivity (in yield and/or product quality)
- Loss of domestic and international markets.

Farm biosecurity plans are strengthened through having a collaborative and regional inclusive approach which identifies a region's vulnerability to threats and engages with community biosecurity promotion and education.

Watch these clips to investigate Biosecurity in NSW further.

NSW Biosecurity Act 2015: a shared responsibility Watch Bruce Christie Deputy Director General Biosecurity and Food Safety with the NSWDPI as he explains how biosecurity affects Australians.

NSW Biosecurity Act 2015: the importance of biosecurity Reg Kidd, Brendan Ostini (Ravecchia Poll Merino Stud) and Allan Dawson (Winyar Merino Stud) have their say on biosecurity, what it means to them and what they are doing on their land.

NSW Biosecurity Act 2015: making your farm biosecure James Sweetapple from Cargo Road Wines talks about measures he has in place to protect his business and how he educates visitors about the importance of biosecurity.

Biosecurity in Our Backyard - Hosted by Costa Watch Costa Georgiadis and the team from NSW DPI discuss biosecurity and careers.

Learning activities

1. **A list of potential and current biosecurity threats have been given in the following table. Use research to briefly identify negative impacts each could have on agricultural production**

Biosecurity threat		Impact to agricultural production
Potential Threats	Citrus Canker to horticulture	

Current Threats	Brown Marmorated Stink Bug to horticulture	
	Rice blast	
	Varroa Mite for bees	
	Foot and Mouth Disease in livestock	
	Serrated Tussock	
	Blackberry	
	Footrot in sheep and goats	
	Leptospirosis in cattle	
	Stripe rust in wheat	

2. **Answer the following past NESA HSC Agriculture question.**
   How does biosecurity help protect Australia's agricultural industries? (NESA 2013 HSC Agriculture Q28.a.ii 5 marks)

Syllabus point

Evaluate biofuel production with respect to world food demands and sustainable and efficient use of carbon

Glossary

Biomass- Organic matter (plant and animal waste and products) used as fuel.

Carbon sequestration- Carbon sequestration in the agriculture sector refers to the capacity of agriculture lands and forests to acts as a carbon sink and remove carbon dioxide from the atmosphere. Carbon dioxide is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass in tree trunks, branches, foliage and roots and soils.

Fossil fuel- Natural, carbon rich fuel formed from the decayed remains of living organisms. Heat and pressure from geological activity over hundreds of millions of years convert the organic matter to fossil fuels: petroleum, coal and natural gas.

Greenhouse effect- The greenhouse effect is a natural process on Earth. Greenhouse gases in the stratosphere absorb infrared radiation from the sun and radiate heat to the Earth's crust keeping Earth at a constant temperature and allowing for life.

Greenhouse gas (GHG)- Gases which accumulate in the earth's atmosphere (stratosphere), that absorb infrared radiation and radiate heat. Gases include: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), chlorofluorocarbons and water vapour (H_2O).

Non-renewable energy- Energy resources that cannot be replaced by natural means on a level equal to its use. Fossil fuels are considered non-renewable energy types.

Renewable energy- Energy resources collected by natural means, which are constantly replaced and do not run out. Renewable energy types include: sunlight, wind, rain, tidal, geothermal and biomass/ biofuels.

Biofuels and world food demands

Global demand for agricultural crops is increasing, driven by a projected 2.3 billion person increase in global population by 2050. Land clearing and more intensive use of existing croplands could meet the increased crop production needed to meet such demand; however, the environmental impact associated with meeting these production needs is unceratain (Tilman, Blazer, Hill, Befort, 2011).

Agriculture already has major global environmental impacts: land clearing and habitat destruction threaten biodiversity; about one-quarter of global greenhouse gas (GHG) emissions result from land clearing; crop production, and fertiliser use impact marine, freshwater, and terrestrial ecosystems. With shortages of non-renewable fossil fuels, especially oil and natural gas, and heavy biomass energy consumption occurring in both developed and developing countries, a major focus has developed worldwide on biofuel production (Tilman et al., 2011).

Renewable energy sources: maize, sugarcane, soybean, wood and crop residues, and animal waste are currently being used to create biofuels. Using renewable resources to create fuel has both benefits and creates conflict. The main conflict surrounds the use of land, water, energy, and other environmental resources, required by both food and biofuel production. The ethical controversy essentially lies between feeding or fuelling the globe.

Fuelling the globe:

- Biofuels offer organic based solutions to the Earth's growing energy problems. Plants used for biofuel production, sequester and cycle Carbon; components of GHG carbon dioxide and methane. Production of second and third generation biofuel types use residual organic products and non-food plant and animal products to make biofuels which offer great promise to the food vs. fuel debate.
- The process of growing the crops, making and using fertilisers and pesticides, and processing plants into biofuels consumes a lot of energy. It's so much energy that there is debate as to whether first generation biofuel-ethanol from crops provides more energy than requirements to grow and process them. Also, much of the energy used in biofuel processing and production comes from coal and natural gas.

Feeding the globe:

- Crop production which has increased productivity and yield while reducing resource use and negative environmental impact is the current focus in agriculture. Everyday increases in research development and technology are allowing us to reach these goals. Biotechnology could provide the answers to developing plant varieties so efficient that they meet both future global food demands and biofuel production needs to replace fossil fuel usage and eliminate world hunger.
- Although much of the land worldwide is occupied by grain and other crops, malnutrition is still the leading cause of death in the world today. The World Health Organization reports that more than 3.7 billion people (56% of the global population) are currently malnourished and that number is steadily increasing. Grains make up more than 80% of the world food supply, and unfortunately, the Food and Agricultural Organization of the United Nations reports that per capita grain production has been declining for the past 23 years. This suggests that the nutritional needs of the human population will require an increasing amount of agricultural resources as food (Tilman et al., 2011). Crops would go to better use as a source of food rather than fuel.

Biotechnology offers the prospect of producing biofuels competitively from readily-available plant material such as stubble, grasses, algae, wood waste and fibre pulp e.g. sugarcane bagasse. This technology is still in the process of being proven commercially viable, but could reduce our dependence on fossil fuels and benefit the environment.

Biofuels and sustainable and efficient use of carbon

The enhanced greenhouse effect and fossil fuels

The Greenhouse effect is a natural process that warms the Earth's surface. When the suns energy reaches the Earth's atmosphere, some is reflected back into space and the rest is absorbed and re-radiated within the atmosphere to the Earth's crust by greenhouse gases.

Human activity including burning fossil fuels, land clearing, mining, urbanisation, agriculture and industrialisation are producing an enhanced greenhouse effect through increasing concentrations of GHGs associated with those activities. This is resulting in increases in global temperatures (global warming) which negatively impacts biodiversity, climatic stability, ocean levels among other negative environmental impacts and agricultural production and distribution.

Carbon sequestration, agriculture and biofuels

Atmospheric concentrations of carbon dioxide (CO_2) can be lowered either by reducing emissions or by taking CO_2 out of the atmosphere and storing it in terrestrial, oceanic, or freshwater aquatic ecosystems. Carbon sinks or carbon sequestration, are processes or activities that remove greenhouse gas from the atmosphere.

Several agricultural practices and technologies have great potential to reduce greenhouse gas emissions and prevent climate change by enhancing carbon storage in soils; preserving existing soil carbon; and reducing carbon dioxide, methane and nitrous oxide emissions. These include:

- Biofuels
- Conservation tillage and cover crops
- Improved cropping and organic matter retention based systems
- Sustainable management with land use changes
- Irrigation and water management
- Nitrogen use efficiency
- Methane capture

There is debate as to whether conventional biofuel production using first generation biofuel food crops (sugarcane, maize, soybeans) are carbon neutral. This is because the process of growing the crops, soil preparation, sowing, harvesting, making and using fertilisers and pesticides, and processing plants into biofuels consumes a lot of energy traditionally sourced from fossil fuels. There is emission offset by the crop through using carbon during growth. Read more at Biofuel breakthroughs bring 'negative emissions' a step closer.

To balance biofuel production, food security and emissions reduction; research and development into new conversion technologies, bio-refinery processes, new sources of biomass and advances in technology in engines that use them, are globally occurring. Biofuel development is being driven by mandates, subsidies, and supportive import-export policies in many countries around the world.

Biofuels show much promise in not only reducing carbon emissions, but also reaching carbon emission negative. Characteristics of possible crops for biomass production include: high productivity, low greenhouse gas (GHG) emissions, and low environmental impacts.

Raw materials which currently show great potential as sources of renewable biomass include:

- Perennial plants grown on degraded lands abandoned from agricultural use
- Crop residues
- Sustainably harvested wood and forest residues
- Double crops and mixed cropping systems
- Municipal, industrial and animal wastes
- Algae

These sources could provide considerable amounts of biomass, without releasing substantial amounts of carbon dioxide through changes in land use. To balance global food security issues biofuel production should transition away from using food crops and toward the more sustainable sources which carry out greater levels of carbon sequestration and can be produced with less impact on the environment.

Biofuel Facts

- Biofuels potentially hold positive solutions for the environment in reducing greenhouse gas emissions and fossil energy usage (efficient use of Carbon)
- Consumption and use of grains for biofuel impact national grain prices and international grain prices. This provides a competing demand for grain to be produced for human consumption, livestock feed and use for biofuel production.
- The reduction in GHG emissions resulting from the use of biofuels and biofuel blends is closely aligned to the Australian Government's Direct Action approach to climate change. Australian biodiesel has the potential to reduce emissions by over 85% in comparison to diesel and Australian ethanol can reduce emissions by approximately 50% (Bioenergy Australia, 2016).
- The "grain deficiency" for the malnourished people in the third world countries is increasing. Possible solutions involve increasing local grain production –through increasing arable land to cropping, using crop varieties with higher yields, using biotechnology and GM varieties with increased production and biofortified traits, and the adoption of more advanced agriculture (Daynard. K, Daynard, T, 2011).
- About 5.7% of global grain production (3.7% after netting out by products) and 10% of global vegetable oil production is now used to make 85 billion and 15 billion litres of ethanol and biodiesel, respectively (Daynard. K, Daynard, T, 2011).
- Food and biofuels are dependent on the same resources for production: land, water, and energy
- Vehicles commercially available for transportation are not currently designed to efficiently run solely on biofuels, with most designed to run on a biofuel/petroleum or diesel mix (Daynard. K, Daynard, T, 2011).

Learning activities

1. **Contrast the use of annual and perennial crops for biofuel production in terms of carbon conservation.**

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2. **Discuss the use of biofuels as alternatives to fossil fuels.**

3. **Evaluate whether biofuel production should be a priority over world food production? Use the scaffold if required to structure your response.**

Evaluate: make a judgement based on criteria; determine the value of:

Description of features/issue:

Points for (advantages):

AND

Points against (disadvantages):

Criteria:

Judgement of each point for/against criteria:

3. Current areas of development in biotechnology

Syllabus point

Describe current developments in biotechnology including biofuels, biopesticides, rumen modification, gene markers, vaccine production, embryo and sperm testing and embryo splitting

Glossary

Artificial Insemination (AI)- Technique which involves the artificial introduction of male sperm into a females uterus or cervix for the purpose of achieving in vivo (internal) fertilisation.

Biomass- Organic matter used as a fuel source

Biofortification- Biofortification is any process whereby the nutritional quality of food crops are improved through agronomic practices, conventional plant breeding or using modern biotechnology approaches.

Embryo- Early developmental stage of a multicellular organism (fertilised and developing ova).

Foetus- Development stage between embryonic stage and birth.

Gene*- A sequence of DNA that encodes all the information to build a specific protein, these are the basic units of heredity.

Gestation-Period of time of development of foetus between fertilisation and birth.

Genome sequencing- The process of determining the complete sequence of an organism genome (the order of nitrogenous bases Adenine, Thymine, Cytosine and Guanine specific to a species).

Multiple Ovulation Embryo Transfer (ET)- A reproductive technique whereby female mammals are administered hormones which make them release multiple ova (eggs) at the time of ovulation. The multiple ova are fertilised using AI or through natural mating. The fertilised embryos are collected from the donor animal and either frozen in liquid nitrogen or transferred into recipient animals.

Nutraceuticals- Foods or food components that provide a medical or health benefit beyond basic nutrition, including the prevention and treatment of disease. Foods containing nutraceuticals are called functional foods.

Pathogen- A biological agent that causes disease or illness to a host. Common examples include: bacteria, fungi, protozoan, viruses, nematodes and invertebrate insects.

Pheromones or parapheromones (male lures) – chemical hormones excreted by living things that control sexual behaviours. Pheromones can be used as biopesticides in plant production to either attract and kill, or disrupt mating of insect pests.

Ruminant – mammals with a modified digestive system involving four stomachs. Carry out rumination (regurgitation and re-chewing of feedstuffs). Rumen contains microflora- fungi, bacteria and protozoan which aid in the digestion of cellulosic material.

Biofuels

Biofuels are combustible fuels created from a range of biomass. The three main types of biofuels are Bioethanol, Biodiesel and Biogas.

There is much global research and development into new biofuel conversion technologies, bio-refinery processes, use of new sources of biomass and advances in technology in engines using biofuels. Biofuel development is being driven by mandates, subsidies, and supportive import export policies in many countries globally.

Biofuels show much promise in not only reducing carbon emissions, but also reaching carbon emission negative. Characteristics of possible crops and biomass for Biofuel production include: high productivity, low greenhouse gas (GHG) emissions, and low environmental impacts.

Raw materials which currently show great potential as sources of renewable biomass include:

- Perennial plants grown on degraded lands abandoned from agricultural use
- Crop residues
- Sustainably harvested wood and forest residues
- Double crops and mixed cropping systems
- Municipal, industrial and animal wastes
- Algae

Biopesticides

Biopesticides are pesticides derived from natural materials. The active ingredients to control pests come from animals, plants, invertebrates and micro-organisms: nematodes, fungi, bacteria, protozoan and viruses. They offer an innovative approach to management of pests in farming systems using natural agents as the active ingredient.

Biopesticide types:

- **Plant extracts** –products or oils extracted from plants. The extracts enhance a plants growth by helping it resist pests. Examples include: pyrethrum derived from *Chrysanthemum cinerariifolium* which non-selectively kill insects on contact at high dosage and act as a repellent at a lower dosage.
- **Microbial pesticides**- products in which living microorganisms (bacteria, fungi, protozoa or virus), or an extract from that microorganism is the active ingredient. Microbial pesticides can range from selective to non-selective to a specific pest pathogen. Modes of action include: activating plant

immune defence, direct action on the fungal pathogen, or preventative occupation at the infection site. Examples include: *Bacillus thuringiensis subsp. kurstaki*, which affects all insects within the family Lepidoptera (moths).

- **Biochemicals-** these chemicals are either produced naturally by plants, animals, insects and microbes; or are equivalents synthetically manufactured. Examples include: 'cuelure' pheromone which attracts Queensland fruit fly (*Bactrocera tryoni*); and synthetic Insect Growth Regulators (IGRs) which prevent egg hatching and larval growth and development.
- **Plant incorporated Protectants (PIPs)-** these are pesticidal substances that plants produce from genetic material that has been incorporated into the plant. Examples include: *Bacillus thuringiensis bacterium*, which has been incorporated into Bt Cotton to disrupt the Cotton bollworm (*Helicoverpa armigera).*

Rumen modification

The rumen fermentation processes play a key role in ruminant nutrition and consequently production. The symbiotic relationship between the rumen microflora and host give ruminants several advantages in digestive and metabolic processes over monogastrics. A disadvantage of ruminant digestion is that it is characteristically inefficient.

Creating greater digestion efficiency and nutrient utilisation in ruminants is achievable through rumen modification. Rumen modifiers may be categorised as:

- Modifiers of the volatile fatty acid (VFA) profile
- Compounds that decrease the risk of acidosis
- Compounds that increase the digestibility of nutrients in feedstuffs
- Compounds that decrease methane emissions

There has been much development in the Australian Beef industry into rumen modification, as funded through Meat and Livestock Australia (MLA). Examples of projects include:

- Transgenic Bacteria in the rumen
- Vaccinal approaches to controlling rumen function
- Using and manipulating the protozoa, fungi, bacteria and rumen enzymes to meet certain targets such as digesting low quality tropical grasses in the Northern Beef Industry and feedlots
- Sourcing and introducing bacteria from other species for biotechnology applications
- Genetics and selective breeding

Follow this link "Reducing Livestock Methane Emissions" to watch Carly Rosewarne from the CSIRO discuss her work on the genomics of microbes in the digestive system of ruminant livestock, with a goal of reducing methane emissions from livestock production systems by using algae.

Follow this link to the MLA's "National livestock methane program" to investigate Australian rumen modification programs

Gene markers

Genes are sequences of DNA. DNA segments (genes), close to each other on a chromosome tend to be inherited together. Due to genome sequencing or gene mapping of different species, we know locations of many genes on chromosomes. A genetic marker is a DNA sequence with a known physical location. Genetic markers are easily identifiable DNA sequences, which we can look for and use to track the inheritance of identified or nearby genes in an organism or offspring.

By taking a tissue, fibre, or blood sample from an organism; genetic analysis may be undertaken to determine the presence of the targeted genetic marker and associated genes. An advantage of using gene marker assisted breeding is multiple genes can be detected in a single genetic analysis.

Gene marker technologies have vast applications in both plant and animal production. Examples include aiding selection of superior individuals for breeding programs. This approach dramatically reduces the time required to identify individual offspring, varieties or breeds which express a desired trait or combination of desirable traits in a breeding program. The technology offers advancement of traditional selective breeding and increases in production through increasing genetic gain.

Australian Projects using marker-assisted breeding:

- Hornless cattle: The Australian Poll Gene Marker test which is helping Australian cattle breeders select the best breeding cattle for their herds. It may also help the industry end dehorning of cattle, an animal welfare issue.
- Protecting wine grapes from mildew: With an estimated cost to the Australian industry of approximately $140 million per annum, powdery and downy mildew are the most economically important diseases in viticulture, causing reduced yield and loss of berry and wine quality. Australian scientists have identified two resistance genes, providing breeders with an alternative to fungicides in the constant battle against the pathogen.
- SNP chip in Sheep industry**-** uses blood or tissue samples from an animal to test for the presence of millions of multiple gene markers in the animals DNA sequence. Gene markers targeted include pedigree testing, tests for horn/poll status, traits for increased growth rate and carcass quality. It then allows the performance data to be added to industry-specific quantitative data collections (Australian sheep breeding values-ASBV's) including BREEDPLAN, LAMBPLAN or MERINOSELECT.
    - Watch "Reading sheep genes (episode 4)" as MLA feedback TV investigates Kim Barnett's use of SNP chips to assist selective breeding and data recording to improve genetic gain in Merino production.
    - Watch "SNP Chip for the Sheep Genome" to investigate research undertaken by the International Sheep Genomics Consortium (ISGC) and the development of the Ovine SNP50 BeadChip, a cutting-edge tool using gene marker technology.

Vaccine production

Vaccination is one of the most efficient and cost-effective practices to prevent infectious disease. Vaccines are produced in order to immunise organisms so that they are resistant to certain pathogens. When an organism is vaccinated, protein in the form of an attenuated, disabled or dead pathogen is administered. As a part of the immune system response, specialised cells involved in the immune system attack the pathogen forming antibodies specific to that pathogen. This results in protective immunity.

Advancements of new technologies and greater understanding of molecular biology and pathogens have led to advances in vaccination production using techniques including: experimental immunology, monoclonal antibodies, recombinant DNA techniques, biopharming (agricultural production of biologically produced pharmaceuticals) and computer chemistry.

Vaccine production in agriculture for human use can be put into the category of Nutraceuticals. Foods containing nutraceuticals are called functional foods.

Biotechnology research aims to find and develop new nutraceutical products that have consumer health benefits. Nutraceuticals are being developed by the food, nutrition and pharmaceutical industries.

Australian examples:

- Australia's Beef CRC's research into the development of "cattle vaccinations using novel anti-cattle tick antigens". The research focussed on screening tick genome sequence data developed by the US Department of Agriculture; to identify potential lead antigens for development and commercialisation of an effective tick vaccine in Australia.

- GM Banana: Vitamin A deficiency (VAD) is a micronutrient deficiency which compromises the immune system and can result in death if untreated. In 2012 the World Health Organisation reported 250 million children were affected by VAD in developing countries where the staple diet is rice which lacks β-carotene (provitamin A). Australian scientists have developed a biofortified GM banana high in Vitamin A to form a potential solution for this disease. Read more at "Golden rice and the struggle over genetically modified food"

Global examples:

- Production of edible and consumable vaccines. These types of vaccines are cheap to produce and have many advantages over the traditional commercialised vaccines. Transgenic plants generated for this purpose are capable of expressing recombinant proteins including viral and bacterial antigens and antibodies. Common food plants like banana, tomato, rice and carrot have been successfully used to produce vaccines against certain diseases: Hepatitis B, Cholera, Ebola and HIV. Watch "How to grow an Ebola vaccine with a tobacco plant" to investigate further.
- Watch "GM cows produce human breast milk"- Chinese scientist produced transgenic cows which produce human breast milk to provide active immunity and an alternative to baby formula.
- Read this article from the Conversation, "Can we 'vaccinate' plants to boost their immunity?" The article investigates developments into using selective breeding and gene transfer methods to develop plant cultivars with selective immunity. It also discusses chemical resistance and explains the plant immune system.

Issues: Nutraceuticals, vaccinations and biofortified products all need to be approved by the appropriate regulators for each country, to ensure safety to human health prior to commercialisation.

Embryo and sperm testing

Embryo and sperm testing are carried in agriculture to increase reproductive efficiency and reduce potential Biosecurity incursions.

Testing for reproductive efficiency: Sperm testing involves processing semen from the male. The semen sample may be either a fresh sample or thawed semen sample. Samples are observed under a microscope and counts for the percentage of live sperm cells and identification of percentage of sperm abnormalities are carried out. These characteristics directly reflect a sire's fertility rate and reproductive potential for use in live mating or artificial insemination (AI) programs.

Embryo testing is carried out when collecting and separating embryos in multiple ovulation embryo transfer (MOET) programs. Fertilised embryos are observed under a microscope and graded according to developmental stage (dependant on the number of cell divisions) and presence of unfertilised ova or degenerate embryos present. For successful ET results and pregnancy rates, only high-grade embryos should be used.

Testing to reduce biosecurity incursions: Embryo and sperm testing, to minimise transfer of infectious disease is carried out for the animal breeding material import and export industry. Australia imports more than 1 million doses of semen and embryos annually. Semen is imported from specified countries for buffalo, cattle, cats, deer, dogs, elephants, giraffes, goats, horses, mice, rats and sheep. Pig semen imports are not permitted from any country. Embryo imports are for cattle, deer, goats, mice, rats and sheep. The main import countries include: the European Union, Canada, New Zealand and the United States of America. Australian import conditions for semen and embryos require the country of export to meet a disease-free status under an International code. Diseases covered by the code include: Foot and Mouth Disease, African horse sickness, rinderpest, vesicular stomatitis, contagious bovine pleuropneumonia, lumpy skin disease and Rift Valley fever. Australian import conditions also require that semen or embryo must be collected at collection centres accredited/approved by the competent authorities in an exporting country according to international codes and agreements.

Embryo and sperm sexing

Embryo sexing- there are various procedures to sex embryos, but all are based on determining the presence of or absence of Y chromosomes (male embryos carry a Y chromosome, while female embryos do not). In order to determine this, a small group of cells from an embryo are removed using a micro-blade. The DNA contained in these cells is amplified to show the presence of the Y chromosome, using a procedure called Polymer Chain Reaction (PCR). A DNA probe is used to determine the presence of the Y chromosome of the cells. The procedure is costly, requires specialist technicians however, is 95% accurate.

Investigate further at AVENTEA's "Embryo Sexing" to see images and description of the technique.

Sperm sexing- this technology is commercially available and used to produce offspring of a desired sex. The technique works on the principle of flow cytometric separation of X chromosome bearing sperm cells from Y chromosome bearing sperm cells. X chromosome bearing sperm cells carry more genetic material and have a larger mass. The flow cytometer identifies the mass and density difference in the different sperm types and separates it accordingly. Sexed sperm is commercially available in Australia, it increases production efficiency and is 95% accurate; however, is more costly than unsexed semen.

Watch "Sexing Technologies" to learn more about semen sexing and its agricultural applications.

Embryo splitting

Embryo splitting is a natural or artificially induced process. It naturally occurs when a single fertilised embryo splits, forming two genetically identical demi-embryos which are clones without identical genetic material (identical twins).

It may artificially be carried out in livestock production. The procedure involves collecting an embryo from a donor animal which is surgically bisected using a micro-blade. The artificial process is fundamentally the same as the natural process. The inner cell mass (blastocyst) of the original embryo must be split, as it contains the cells which continue to divide and develop into a foetus. The divided embryos may then be transferred into recipient animals for foetal development throughout gestation.

Watch "Learn how identical twins can be made (mammals)", to view an embryo being artificially split. The cell mass is the blastocyst and shell-like sphere is the zona pellucida. You will observe the zona pellucida and blastocyst being bisected.

Learning activities

1. **Use research to summarise an example of current Australian developments in the following biotechnologies.**
   Summarise your findings in the following table.

Biotechnology Type	Example	Applications for Australian agricultural production
Biofuels		
Biopesticides		
Rumen modification		
Gene markers		
Vaccine production		
Embryo testing or sexing		
Sperm testing or sexing		
Embryo splitting		

2. **Identify Australian agricultural industries that would benefit from embryo and sperm sexing.**

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3. **Describe current developments in biotechnology with reference to three of the following.**
    - Biofuels
    - Embryo splitting
    - Biopesticides
    - Gene markers
    - Rumen modification
    - Embryo and sperm testing

Syllabus point

Discuss a current biotechnology development

In agriculture, research and development bodies globally develop new biotechnologies to produce food, fibre and fuel more efficiently while reducing degradation to the environment. The new developments and technologies are becoming available at an exponential rate.

Investigate these links to learn more about interesting applications using biotechnology with great potential to revolutionise agricultural production.

Animal cloning- Cultivating Cloned Animals

Biofortification- 'Biofortification': Super-nutritious crops could help millions of undernourished children

Biotechnology gene modification and breeding methods- Methods of Modification

Gene editing- What is CRISPR gene editing, and how does it work?

Learning activities

1. **For a current biotechnology development of your choice, research and summarise the following.**
   - Describe the technology
   - Explain its potential use
   - Summarise a case study or project using the technology
   - Outline the advantages and disadvantages associated with the biotechnology
   - Assess the feasibility of the biotechnology

Tips: If the technology is established and/or commonly used in production it is probably too old to study.
Topics to research must be applicable to agricultural production and could include both non-GM biotechnology types as well as GM biotechnology types but do not have to be limited to the biotechnology innovations outlined in the syllabus.

2. **Discuss a current biotechnologies' potential use in Australian agriculture. Use your research from Activity 1 and the following scaffold to assist to map your discussion.**

Discuss: identify issues and provide points for and/or against

Issues identified

AND/OR

Points for:

Points against:

1. Benefits and problems of biotechnology and genetic engineering in agricultural industries

Syllabus point

Analyse the conflict between increased production and ethical concerns in biotechnology innovation

Over the last century, the global population has quadrupled. In 1915, the global population was approximately 1.8 billion. Currently, according to the United Nations, the global population is approximately 7.4 billion people and it is predicted to reach 9.7 billion by 2050. This growth, along with rising incomes in developing countries (which cause dietary changes such as eating more protein and meat) are increasing global food, fibre and fuel demand and agricultural production (Elferink and Schierhorn, 2016).

As a result, global demand for agricultural products food, fibre and fuel, is expected to increase anywhere between 59% to 98% by 2050. This will shape agricultural markets in ways never seen before. Producers worldwide will need to increase crop and agricultural production by either increasing the amount of agricultural land to grow crops which has negative sustainability and environmental impacts; or by enhancing productivity on existing agricultural lands through efficient fertiliser, chemical and irrigation usage, carrying out research based agriculture production, farming highly efficient and productive plant and animal varieties and adopting new technologies and methods of production. This all must be accomplished with a long-term focus on sustainability, environmental impact and conservation of natural resources regardless of impacts of agricultural land loss due to urbanisation, resource degradation and climate change (Elferink and Schierhorn, 2016).

Biotechnology innovation offers limitless opportunities to provide solutions to these problems of efficient increased agricultural production, food security, renewable fuel alternatives, poverty reduction, malnutrition and environmental conservation.

There are many ethical concerns which surround the use of biotechnologies in agriculture which must be addressed for commercialisation and societal acceptance and adoption. The ethical issues, both positive and negative, can be divided into main areas:

- **Consumer concerns-** For example: consumer health, safety concerns and consumer rights; lack of understanding of technologies; the use of gene technologies and development of GM pharmaceuticals; reluctance to adopt unfamiliar technology; animal welfare
- **Humanitarian concerns-** For example: food security; malnutrition; treatment of disease; poverty reduction; the potential for a new phase of comparative disadvantage and increased dependency on technologies from the developing world
- **Environmental concerns-** For example: increased production with less impact on resources and environment; evolution of renewable energy sources; potential carbon neutral or carbon negative farming; superior high production and efficient plant and animal cultivars and species; evolution of 'super pathogens'; potential impacts on biodiversity, food chains, and environment
- **Economics/ production concerns–** For example: impacts of multinational corporations controlling technologies; greater profit and ease of production for farmers and all aspects of the supply and production chain; impact on markets; the mismatch between grower needs and research; limited technical resources; reluctance to adopt unfamiliar technology; costs on production
- **Legal concerns-** For example: intellectual property rights and patents which could potentially lead to monopolisation of technology knowledge and control; increased private sector investment into research and development; multinational corporations controlling technologies; countries legislative positions on the use of biotechnology, for example, regulatory systems; growing and labelling; animal welfare.

Learning activities

1. **Group debate**
   - **Separate into pairs to complete the following activities. Your pair will be assigned a position on the use of biotechnology to increase agricultural production. Mark it below:**

☐ I am in favour of biotechnology use to increase agricultural production

☐ I am against biotechnology use to increase agricultural production

- **Find evidence to support your assigned position. List two pieces of specific evidence to support each of the five ethical concerns. Use your learning from the whole unit or conduct support research.**

  Consumer concerns

  Humanitarian concerns

  Environmental concerns

  Production/ economic concerns

  Legal concerns

- **Formulate your argument to support the position you have been assigned. Summarise it below in 5 paragraphs**

- In your pair, discuss your final positions on the use of biotechnology for increased agricultural production. Together discuss your evidence for each position. Identify which portions of the position are based on scientific research and which are social issues. List them below.

Scientific issues	Social issues

- Find a group with the opposing line of argument. Conduct a class debate or group debate to identify opposing issues.
- The use of biotechnology to increase agriculture has many ethical issues. Reach a consensus combining two opposing views based on multiple lines of evidence. Below formulate a new position, which addresses the need for increasing agricultural production and issues surrounding biotechnology use. Keep in mind the consensus may have multiple solutions.

2. Apply your understanding of this topic to complete the following past HSC Agriculture examination question.
Explain the potential conflict between the need for increased production and ethical concerns relating to the use of biotechnology in agriculture. (NESA 2013 HSC Agriculture Q29.b 12 marks)

2. Potential applications of gene technology and biotechnology in agriculture

Syllabus point

Investigate uses of biotechnology in agriculture such as genetic modification of crops to incorporate resistance to pests and diseases, herbicide tolerance, slowing the ripening of fruit or altering the timing and duration of flower production

Glossary:

Antimicrobial- An antimicrobial is an agent which kills microorganisms or inhibits their growth for example antifungal or antibacterial agents also known as Biochemicals or Biopesticides.

Broad spectrum herbicide- Broad spectrum or non-selective herbicides do not discriminate between monocotyledon or dicotyledonous plants and kill a broad range dependant on application rates and mode of action for example Glyphosate

Climacteric- Climacteric is a stage of fruit ripening associated with increased ethylene production and a rise in cellular respiration. Climacteric is the final physiological process of fruit maturation and the beginning of fruit senescence (death).

Dicotyledon- Flowering plants. Characteristics include: an embryo containing two cotyledons (seed leaves), a central taproot and broad leaves with net venation. Examples include Lucerne, medics, legumes, thistles, canola, cotton, shrubs and trees.

Ethylene- Ethylene is a plant produced hormone which controls fruit ripening. Ethylene is responsible for the changes in texture, softening and colour of fruit. Plants produce different amounts to control fruit ripening. Climacteric plants produce large amounts of ethylene and non-climacteric plants such as strawberries and cherries do not produce large quantities.

Florigen- Florigen is a plant produced hormone produced in the leaves of flowering plants which triggers and controls flowering.

Gibberellin- Gibberellins are plant produced hormones that regulate various developmental processes including stem elongation, germination, dormancy, flowering, flower development and leaf and fruit senescence (death).

Herbicide resistance- Resistance is the ability of an individual plant to survive and reproduce after herbicide application that would usually kill a normal population of the same species.

Monocotyledon- Flowering plants. Characteristics include: an embryo containing one cotyledon (seed leaf); fibrous root system and blade-like leaves with parallel venation. Examples include wheat, barley, rice, corn, phalaris, cocksfoot and ryegrass.

Pathogen- Pathogens are biological agents that cause disease or illness to a host. Common examples include: bacteria, fungi, protozoan, viruses, nematodes and invertebrate insects.

Photoperiod- Photoperiod is the period of time each day during which an organism receives light.

Photoperiodism- Photoperiodism is the physiological reaction of an organism in response to the length of daylight or night. Photoperiodism occurs in both agricultural plants and animals.

Phytochrome- Phytochrome is a blue-green chemical pigment found in plant light receptors (phytochromes), which allow plants to detect light. They are crucial to plant survival and reproduction and regulate flowering to match environmental seasons.

Selective herbicide- Selective herbicides treat and kill targeted plants, for example, broadleaf herbicides target only dicotyledonous plants

Vernalisation- Vernalisation is the qualitative or quantitative dependence of plants on exposure to low temperature to flower. Different plant species have different vernalisation requirements.

Genetic modification of crops to incorporate resistance to pests and diseases

Since the domestication of plants for agriculture, humans have searched for crop plants that can survive and produce in spite of pest and disease. Knowingly or unknowingly, ancient farmers selectively bred and domesticated crops, selecting for pest and disease resistance; through actions as simple as collecting seed from only the highest yielding plants.

With the advent of genetic engineering and gene modification, genes for pest and disease resistance now can be selectively altered within a plant or genes transferred within and between species. This can quickly and deliberately develop new cultivars and varieties with specific pathogen resistance. The technology offers the development of user- friendly, consumer friendly and environmentally sustainable high yielding crop varieties that can meet the demands of sustainable 21st century agriculture.

There are many commercial examples of crop varieties using biotechnologies for pest and disease resistance. Follow the links to investigate further

- "Genetically modified crops: insect resistance" this article addresses recent advances in genetic engineering using *Bacillus thuringiensis* (Bt) to control insects pests in food and fibre crops.
- "Protecting wine grapes from mildew" with an estimated cost to the Australian viticulture industry of approximately $140 million per annum, powdery and downy mildew are the most economically important diseases in viticulture, causing reduced yield and loss of berry and wine quality.

Australian scientists have identified two resistance genes, providing breeders with an alternative to fungicides in the constant battle against the pathogen.

- "Incorporation of pea weevil resistance into a cultivar field pea" this is the final report from a Grains Research and Development Corporation (GRDC) project to develop a pea weevil resistant field pea cultivar using gene marker technology.

Genetic modification of crops to incorporate herbicide tolerance

Weed control is a major challenge in crop production. Weeds affect crop yield and quality through competition for resources. Herbicide use is an effective strategy to control weeds, however, has negative environmental and sustainability side effects. Selective herbicides which target specific plants (weeds) have traditionally been used in cropping systems for weed treatment. The use of selective herbicides while offering effective target weed treatment if used properly, can increase the need for multiple selective chemicals to be used to treat multiple weed varieties. The use of broad spectrum or non-selective herbicides such as Glyphosate; which affect a broad variety of plants and weeds is a more efficient and environmentally friendly solution.

Genetic modification offers the potential to add herbicide tolerance without sacrificing other agronomic and disease resistance attributes of crops. Herbicide tolerance is a plants' ability to withstand a particular herbicide. Herbicide tolerant crops are designed to tolerate specific broad spectrum herbicides which kill the surrounding weeds, but leave the cultivated crop intact. In Australia, Herbicide resistant GM Canola and GM cotton varieties are commercially grown.

- "Herbicide resistant crops" this article discusses Australian developments in herbicide resistant crop technology.

Biotechnology in crops to slow the ripening of fruit

Ripening is the end of the maturation process for certain fruits, when they become sweeter, softer and juicier. From its onset ripening only takes a few days before fruit decay is initiated depending on the plant type. This unavoidable process can lead to great losses from the farm to consumer. Slowing fruit ripening has the potential to reduce spoilage during transportation, storage and after purchase. Biotechnology offers solutions to reduce spoilage by delaying fruit ripening (Crop Life International, 2016).

Climacteric fruits such as apples, bananas, avocados, pineapples, apricots, melons and tomatoes; ripen in response to cellular respiration and the plant hormone ethylene being produced in large quantities. They are usually harvested prior to ripening so the climacteric process which occurs rapidly is timed during transport and storage. Climacteric fruit types would benefit the use of biotechnology to delay ripening (Crop Life International, 2016).

The use of the technology involves fruit being harvested on farm whilst green, to survive transport. The fruit is shipped in refrigerated transport to slow cellular respiration and ethylene production. The ripening process is then induced by spraying the fruits with ethylene gas at the destination. A side effect is that quality and taste can be compromised (Crop Life International, 2016).

Biotechnology uses to slow the ripening of fruit include: controlling the amount of ethylene a fruit produces by 'switching off' or decreasing the amount produced through gene modification; modifying fruits ethylene receptors; or using antimicrobial solutions to delay ripening and decay. These biotechnology methods can extend a fruits shelf life, reduce food wastage, enhance fruit quality and flavour and open domestic and export market opportunities (Crop Life International, 2016).

- "War on waste: Antimicrobial borne by feral foxes slows decay saving food and money" this article investigates the Australian Cluster Biotechnology Group's research into using micro-organisms from feral foxes to create an organic microbial solution to manipulate fruit and vegetable decay.

Biotechnology in crops to alter the timing and duration of flower production

The timing of flowering in plants is determined and initiated by genetic and environmental influences: day length, temperature and stress (water, nutrient availability, salinity and pH). Plants flower to produce seed as a reproductive process. Some species naturally delay flowering by slowing their metabolism.

The onset and timing of flowering have great importance to plant production. Temperature and day length (photoperiod) are major determinants of the rate of plant development and the onset of flowering. The effect they have on plant development includes:

Temperature-

Vernalisation requirements- many plants have evolved to sense and require prolonged periods of cold temperatures to cue flowering and seed development. It is an adaptation to suit environmental conditions to ensure flowering occurs in Spring or Summer. If vernalisation requirements are not met the plant will not produce gibberellin hormones to transition from vegetative to reproductive bud development, resulting with low yield. Vernalisation requirements are seen in temperate, 'winter growth' plants including winter crops (wheat, barley, oats, ryegrass) stone fruits (cherries, peaches, nectarines) and pome fruits (apples, pears). Warmer temperatures can have a negative impact on crop yield by shortening development stages.

Photoperiod-

Photoperiod has a greater effect on plant onset of flowering then temperature, as temperature alone is not a reliable indicator of the time of year. Resultantly, plants have evolved photoperiod adaptations. Plant photoperiod requirements are based on night length (hours of darkness) which are measured in the plant by light receptors in leaves containing the chemical phytochrome. The ratio of darkness to daylight hours stimulates the release of the hormone florigen which controls the transition of vegetative buds to reproductive buds. Based on their photoperiod and flowering response, plants are classified as:

- Short day plants- flower in response to less than eight and a half hours of daylight (wheat, sub-clover and oats)
- Long day plants- flower in response to greater than eleven hours of daylight (maize)
- Day-neutral plants- carry out flowering regardless of night length (tomatoes)

Research is being carried out to manipulate genes controlling the onset of flowering in plant crops to create commercially viable solutions and cultivars for agriculture, floriculture and horticulture industries. Biotechnology techniques currently commercially used in industry to manipulate onset and duration of flowering include the synthetic application of hormones, including:

- The use of synthetic gibberellins in the form of gibberellic acid which is used to stimulate out-of-season growth and manipulate flowering in plants which would otherwise have specific photoperiod and or vernalisation requirements. Investigate commercial application of gibberellic acid use at "Year round production of Australian daisies as flowering pot plants".
- The use of the hormone florigen is a floral inducer to manipulate flowering onset. Investigate commercial Australian applications of manipulating chrysanthemum flowering using florigen at "Florigen and anti-florigen: flowering regulation in horticultural crops".

Learning activities

1. **Complete the following activities specific to each topic area**

   a) **Genetic modification of crops to incorporate resistance to pests and diseases**

   - Outline uses of genetic modification in crops to incorporate pest and disease resistance

   - Summarise and draw conclusions regarding a specific Australian example of the biotechnology

   b) **Genetic modification of crops to incorporate herbicide tolerance**

   - Outline uses of genetic modification in crops to incorporate herbicide tolerance

   - Summarise and draw conclusions regarding a specific Australian example of the biotechnology

   c) **Biotechnology in crops to slow the ripening of fruit**

   - Outline uses of biotechnology to slow the ripening of fruit

- Summarise and draw conclusions regarding a specific Australian example of the biotechnology

d) Biotechnology in crops to alter the timing and duration of flower production

- Outline uses of biotechnology to manipulate the timing and duration of flower production

- Summarise and draw conclusions regarding a specific Australian example of the biotechnology

2. **Apply your understanding of biotechnology and genetic modification in crop production to complete this past HSC Agriculture NESA question.**
   Discuss the uses of, and implications for Australian agriculture of, genetically modified crops. In your answer, include specific examples. (NESA 2015 HSC Agriculture Q28.b 12 marks)

3. Biofuel production

Syllabus point

Describe ways biofuel is produced from *grain, *sugar, *vegetable oils, *algae and *green waste/straw

Biofuels are combustible fuels created from biomass (organic material). In other words, fuels created from recently living plant or animal matter, micro-organisms and organic wastes; as opposed to ancient organic matter (fossil fuels) in hydrocarbons. All biofuels come from renewable origins and are based on solar energy which is converted to chemical energy through photosynthesis.

The most common types of biofuels are Bioethanol, Biodiesel and Biogas. Less common biofuel types for commercial use include: bioalcohol, vegetable oil and syngas.

The two main types of biofuels currently in production for commercial industry use in Australia are bioethanol and biodiesel. Bioethanol is used as a replacement for petrol and is being produced from sugarcane molasses, grain sorghum and waste wheat starch. Biodiesel is used as a replacement for diesel and is being produced here from used cooking oil, tallow and vegetable oil from canola seed and other oilseeds.

Bioethanol: Bioethanol is mainly produced by carbohydrate (e.g. sugar or starch) fermentation. It can also be manufactured by a chemical process reacting ethylene with steam called ethene hydration. It can be used as a replacement for, or additive to petroleum.

Biomass used to create Bioethanol includes:

- Energy cops-maize, sugarcane molasses, wheat, sorghum, soybean, palm sugar;
- Agricultural residues- crop stubble and residues, straw, stem, stalk, leaves, husk, shell, peel, pulp, cobs, fibrous sugarcane and sorghum bagasse, perennial grasses, algae.

- Forestry wastes- tree thinning and cuttings, bark, needles/leaves, stands with disease or insect damage, sawdust, timber and forestry residues.

Biodiesel: produced by extracting naturally occurring oils from plants, seeds and animal fats in a process called transesterification. Biodiesel can be combusted in diesel engines. Biodiesel is very similar to traditional mineral diesel and is chemically known as fatty acid methyl. This oil is produced after mixing the biomass with methanol and sodium hydroxide. The chemical reaction produces biodiesel. Biodiesel is very commonly used for diesel engines after mixing up with mineral diesel. In many countries, manufacturers of diesel engine are focusing on developing engines that work well with biodiesel.

Biomass used to create Biodiesels includes:

- Energy crops- canola seed, palm oil, soybeans, mustard, safflower, sunflower, jatropha;
- Agricultural residues- animal fats (tallow), used and waste vegetable oil, algae oil
- Forestry wastes- eucalyptus oil

Biogas: A mixture of gases composed largely of methane (CH_4) and carbon dioxide (CO_2). Biogases are produced during the natural decomposition of organic material in an airtight environment (anaerobic digestion of organic matter). This methane is the same flammable component found in natural gas derived from traditional fossil fuels. The process involved with biogas creation is anaerobic digestion or anaerobic fermentation; carried out by micro-organisms. Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen.

Biomass used to create Biogas includes:

- Energy crops- crop silage e.g. maize silage.
- Agricultural residues: animal residues (including manure, bedding and litter), fresh produce wastage, food processing wastes, algae.
- Human residues: methane and CO_2 from landfill, compost, food scraps, sewage sludge, industrial wastes, glycerine as the product from Biodiesel production.

Biofuel Categories

Biofuels are grouped into four categories based on the biomass source used to produce them. These are first generation, second generation third generation and fourth generation biofuels.

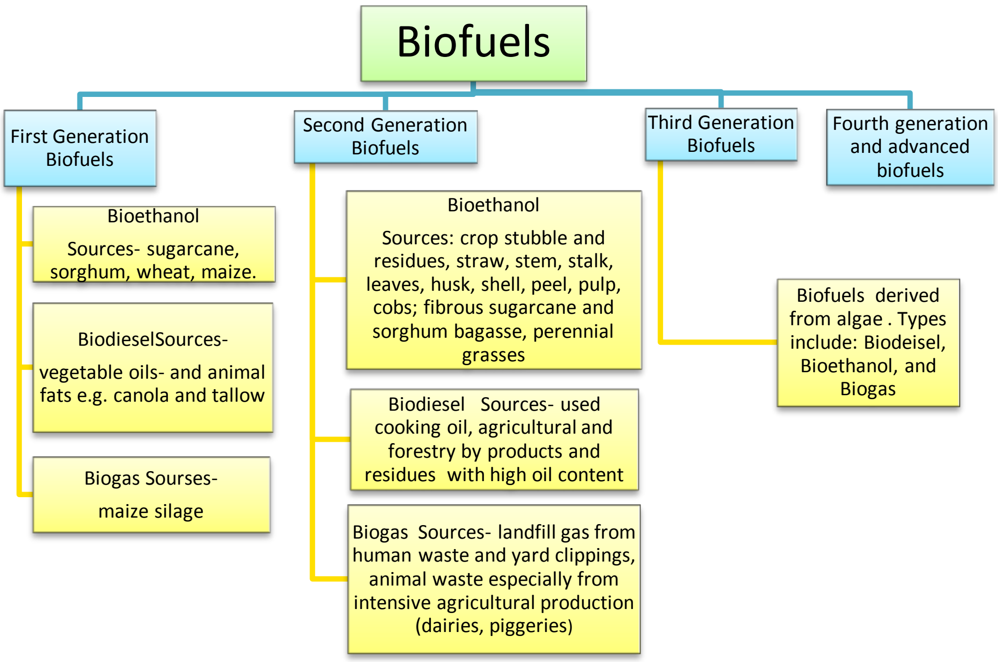
Depending on the origin and production technology of biofuels, they are generally called first, second and third generation biofuels while fourth generation biofuels are emerging at the research and development level which make use of novel synthetic biology tools (Aro, E.M, 2015).

- **First generation biofuels**: are sourced from crop plants that can be used for human consumption and stockfeed. They contain high levels of carbohydrates (sugars or starches), oils and cellulose. They negatively impact food security.
    - Watch PIEFAs' "Biofuels from Sorghum to Ethanol" to investigate sorghum use to produce bioethanol at the Dalby Biofuel plant
    - Watch "Ethanol on Modern Marvels" to investigate an American maize ethanol plant and processing line
- **Second generation biofuels**: rely on using biomass that is not suitable as food. Second generation biofuels are produced from sources of non-edible lignocellulosic material (such as seeds, stem and husk), non-food materials (such as crop residues, straw, stubble, sugarcane and sorghum fibrous bagasse, peel, husk, shell), forest residues (such as sawdust); purpose-grown energy crops on marginal lands; and human waste (such as paper, pulp and cardboard). This material is more difficult to break down using fermentation, so requires pre-treatment before processing.

- Watch [Bioenergy: America's Energy Future] to investigate the process of second generation cellulosic bioethanol production and biofuel
- Watch [Biofuels - Ethanol from Cellulosic Feedstocks at SDSU - Pretreatment] to investigate the cellulosic fermentation and pre-treatment processes used in creating second generation biofuels
- Watch "Breakthrough: Using Microbes to Make Advanced Biofuels" to investigate the use of genetic engineering to breed plant and microbe varieties with increased efficiency to produce second generation biofuels.

- **Third generation biofuels**: based on lipid production from algae. Presently under extensive research and development, to improve the metabolic production of fuels and separation process in bio-oil production and lower production costs.
  - Watch "UTS C3: Algal Biofuels research programs" to investigate research and development in algal Biofuel production in Australia.
  - Watch ""Energy 101-Algae to Fuels"" to investigate American algae farming and processing and the technologies potential.
  - Watch "We Can Power The World With Algae!" to investigate the uses of algae for biofuels and evaluate its potential in the fuel industry.
- **Fourth generation biofuels**: are expected to bring fundamental breakthroughs in the field of biofuels. Still, in the research and developmental stage, this biotechnology involves bioengineering synthetic living direct solar energy converters (including algae and cyanobacteria), with metabolically engineered microbial fuel production pathways. This synthetically engineered and produced technology would allow fuel production without a biomass stage.
  - Watch The Artificial Leaf - Jared Scott & Kelly Nyks - GE FOCUS FORWARD to see an engineered synthetic leaf in action.

First, second, third and fourth generation Biofuels may all be further categorised as producing Biodiesel, Bioethanol or Biogas, dependant on the biomass source they are created from. See the figure below.



Learning activities

1. Use research to describe the following processes:

- Fermentation to produce bioethanol

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- Transesterification to produce biodiesel

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- Anaerobic digestion to produce biogas

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- Cellulosic fermentation to produce second generation biofuels

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2. Complete the following table by answering a)-c). The first example has been given.

a) Identify the biofuel conversion process/es for the biomass
b) Identify the fuel type/s produced
c) Identify whether the biomass produces a first, second or third generation biofuel

Biomass	Biomass	a) Conversion process/es	b) Fuel type/s	c) Biofuel type
Livestock manure	Livestock manure	Anaerobic digestion	Biogas	Second generation Biofuel
***Grain**				
***Sugar**				
***Vegetable oils**				
***Algae**				
***Green waste/straw**				
Sugarcane bagasse				
Wood chips				
Eucalyptus oil				
Maize silage				
Landfill				
Cyanobacteria				

**Syllabus requirements*

3. **Describe methods used to produce biofuels in Australia (NESA 2015 HSC Agriculture Q28.a.ii 6 marks)**

4. **Discuss the production and use of biofuels as alternatives to fossil fuels (NESA 2016 HSC Agriculture Q28.b 12 marks)**

Syllabus point

Identify and describe industries or activities that consume biofuel products

Industry is increasingly embracing biofuels as an essential fuel alternative to fossil fuels both currently and for the future. The technological developments from research, to provide commercial economically viable and energy efficient, sustainable biofuels are evolving rapidly.

Follow these links to investigate examples of Australian industry and activities which are embracing, consuming and developing biofuels.

- "Australia's first grain-to-ethanol plant" The Dalby Biorefinery is utilising sorghum grain, which is traditionally a livestock feed, to produce Bioethanol for commercial use. The biorefinery is Australia's first grain to ethanol plant. It purchases around 2000,000 tonnes of sorghum grain per annum to produce approximately 76 million litres of fuel-grade ethanol.
- "Edwina Beveridge: Turning pigs' poo into power" Watch Edwina Beveridge as she describes management and processes on Blantyre Farms and piggery near Young. Blantyre Farms has a methane digestion plant on site. They capture methane from livestock residues to create energy to run the operation. Through methane capture and conversion to electricity, the farm is not buying in electricity and producing electricity in surplus of operational needs.
- "Australian Biogas Benefits- Pork CRC" Watch multiple Australian case studies in the Pork Industry which use methane capture to produce Biogas and create sustainable energy on farm.

- "Using Madowla Park biodiesel -cost savings at Mossrock Australia" Watch Peter O'Donnell, General Manager of Ecofuels Australia, describe the fuel-intensive business operation at Mossrock Australia which creates and distributes mulch. Chris Wearne, General Manager of Mossrock, describes the company's current and planned consumption of biodiesel and the associated cost savings and Biomass types they are using to create biofuels.
- "Madowla Park biodiesel plant - grinding the oilseed" Watch Peter O'Donnell, General Manager of Ecofuels Australia, as he explains the process whereby canola seed is ground to extract oil for making biodiesel at Madowla Park.
- "Farm based algae production" The University of Queensland has established an Algae Energy Farm to cultivate and harvest microalgae for a range of uses, including fuel and as a feed supplement for beef cattle. Watch lead researcher Professor Peer Schenk describe the algae farm setup and results.
- "Annastacia Palaszczuk closer to her pledge of developing Australia's first biofuels industry" Watch Queensland premier Anastacia Palaszczuk and her plan to develop an advanced Biofuel refinery in Gladstone to produce fuel for international maritime fleets, jet fuel and the domestic fuel market.

Learning activities

1. Carry out research to identify and describe at least two industries that consume biofuel products.

1. Research into technical developments

Syllabus point

Analyse a research study of the development and/or implementation of ONE agricultural biotechnology in terms of:

- Design of the study
- Methodology of the study
- Collection of data for the study
- Presentation of data
- Analysis of data
- Conclusions and recommendations

Selecting and analysing a research study

There are a number of research studies available on technological developments; however, it is important you select a **published** research study focused on a **recent** agricultural technology. As a general rule of thumb, if the technology is established and/or commonly used in production it is probably too old to study. To enhance learning and engagement select a research study related to your local context or students interests.

Analysis of a research study includes identifying the components of the study and relationships between components. Focus questions, such as the following may help with analysis of a research study:

- Who is the author and what are their qualifications?
- What is the problem they are solving or the goal of the research?
- What is their approach/methodology for solving the problem?
- What are the benefits and limitations of their approach/methodology?

- How did the author collect and analyse their results?
- What conclusions did they make from their results?
- What application/useful benefit do the researchers/you see for this work?

Amanda Graham suggests techniques to help understand and analyse research studies in her article A Guide to Reading and Analysing Academic Articles.

Sample research studies

- The power of 28 microsatellite markers for parentage testing in sheep**-** this article delivers the findings of a study into using microsatellite markers (MST) a DNA profiling technique developed with the aim to reduce errors in pedigree records of Merino sheep.
- High protein- and high lipid-producing microalgae from northern Australia as potential feedstock for animal feed and biodiesel- this article delivers the findings from a study which sampled and tested a variety of native Australian microalgae strains to identify potential varieties for animals feed and biodiesel production.
- Golden bananas in the field: elevated fruit pro-vitamin A from the expression of a single banana transgene- this article delivers the findings of a field trial of transgenic Cavendish bananas developed with enhanced levels of Vitamin A grown in Australia.
- CRISPR/Cas9-mediated mutagenesis of the white gene in the tephritid pest Bactrocera tryoni (Queensland fruit fly)- this article delivers the findings of a project which uses CRISPR gene editing to develop sterile insects to be utilised in biological control strategies for the Queensland fruit fly.

Learning activities

Analysing a research article template

Abstract

The abstract is a summary of the entire article. It contains all the key points that you need to know to understand the work performed. You should still have questions after reading the abstract, but it should be enough information to help you understand the article as a whole. In your article:

What was studied?

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Which agency conducted this research?

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How was this research conducted? (Basic outline)

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What was determined by this research? (Final conclusions of the researchers)

The Introduction

An introduction usually begins with background information which is obtained by credible sources outside of the research conducted in the experiment. It aims to give a basis for the experiment being conducted.

What are key pieces of information provided by the researchers in their introduction?

Following the background information the article will address the aim of the experiment (the question the researchers are trying to answer), the hypothesis (predicted outcome) and a rationale (evidence they have researched to support their hypothesis).

Aim - What is the research question addressed by this research?

What is the hypothesis?

What is the rationale?

Method

This section provides detailed information about how the experiment was conducted.

Briefly summarise how the researchers conducted the experiment:

Identify how the researchers carried out experimental design in terms of:

- **Standardisation:**

- **Replication:**

- **Randomisation:**

- **Control:**

Results

The results section lists the raw data collected and trends analysed, usually in graphs. This section may refer to data collected as being 'significant'. 'Significant' means the data collected was statistically different to the controls within the experiment, "no significant difference' means data was statistically the same as the controls or not a big enough difference to have an impact on the outcome.

Summarise their results here. What key pieces of information did the researchers collect? List them all:

Discussion (and Conclusion)

This is the most important section of the research article. It will state whether or not the hypothesis was supported by the data. It will conclude with the implications of the researcher's work, if it will have an effect on the industry and describe where research would need to continue to advance or improve this technology.

Did the data collected support the author's hypothesis? Explain:

What impact do the authors think their work will have on their respective field? In other words, how do they think their work will affect the advancement of their field?

What do the authors believe will be the next step in this work?

How could the experimental design have been improved? Explain:

1. **Apply your understanding by completing this past HSC Agriculture question.**

In this elective, you have analysed a research study relating to the development and/or implementation of an agricultural biotechnology. Identify this study and complete i) and ii) (NESA 2014 HSC Agriculture Q28.a i), ii) 8 marks)

i. **State a conclusion and a recommendation from this research**

ii. **Explain how the design of the research study contributed to the validity of its conclusions. In your answer include specific examples.**

Syllabus point

Explain the need for research in the development of agricultural technologies

Research and development for agricultural growth

Research and development (R&D) into agricultural technologies is important to current and future generations and can:

- Support environmentally sustainable management practices and natural resource management.
- Enhance productivity and the economic viability and sustainability of agricultural production and commodities.
- Ensure food security for an ever-increasing population.
- Address changing consumer demands and preferences.
- Improve animal husbandry practices and animal welfare standards.
- Decrease reliance on external inputs such as water and chemicals.
- Increase the reliability of climate and weather predictions.
- Help producers prepare for and adapt to climate variability.
- Protect our industry, environment and society from the impacts of pests and diseases.
- Spurs economic growth and development; research and technology transfer

Further investigate R&D at the NSW DPI Agriculture research webpage.

Learning activities

Apply your understanding by completing the past HSC Agriculture questions.

1. **Why is there a need for ongoing research into agricultural technologies related to agri-food, fibre and fuel? (NESA 2013 HSC Agriculture Q29.a.i 3 marks)**

2. **Why is research required when developing agricultural biotechnologies? (NESA 2016 HSC Agriculture Q28.a.i 3 marks)**

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Agriculture- Stage 6 HSC- Elective 1 – Agri-food, Fibre and Fuel Technologies

Outcomes	Content
H3.4 evaluates the management of the processes in agricultural systems **H4.1 justifies and applies appropriate experimental techniques, technologies, research by methods and data presentation and analysis in relation to agricultural problems and situations** **H5.1 evaluates the impact of innovation, ethics and current issues on Australian agricultural systems.**	• Define DNA, gene, genetically modified organism (GMO), gene markers, genetic engineering and protein synthesis • Describe the implications of biotechnology in the agri-foods, fibre and fuel industries • Outline the importance of food safety and labelling of GMOs • Discuss the issues relating to food production using GMOs • Examine regulations that surround development and use of GMOs and biotechnology • Explain the role of biosecurity • Evaluate biofuel production with respect to world food demands and sustainable and efficient use of carbon • Describe current developments in biotechnology including biofuels, biopesticides, rumen modification, gene markers, vaccine production, embryo and sperm testing and embryo splitting • Discuss a current biotechnology development • Analyse the conflict between increased production and ethical concerns in biotechnology innovation • Investigate uses of biotechnology in agriculture such as genetic modification of crops to incorporate resistance to pests and diseases, herbicide tolerance, slowing the ripening of fruit or altering the timing and duration of flower production • Describe ways biofuel is produced from grain, sugar, vegetable oils, algae and green waste/straw • Identify and describe industries or activities that consume biofuel products • Analyse a research study of the development and/or implementation of ONE agricultural biotechnology in terms of: - design of the study -methodology of the study -collection of data for the study -presentation of data -analysis of the data conclusions and recommendations • Explain the need for research in the development of agricultural technologies